The Honourable John Bracken,
Premier of Manitoba.

Sir:

I have the honour to submit herewith a report on The Soils of Manitoba, being Project No. 14 under the Economic Survey, and the fifteenth of a series of reports covering many phases of the economic and social life of the Province. This report is the work of Professor J. H. Ellis, of the University of Manitoba.

I have the honour to be, Sir,
Your obedient servant,
C. B. Davidson,
Director.

Winnipeg, Manitoba,
September 15th, 1938.

"SOIL AND SOUL"

"The earth a bit of star-dust is,
And all of us but smaller bits,
Of that celestial stuff.
In each of us, a bit of Soil
That makes us kin
To all that breathes;—
In each of us, a bit of Soul
That makes us kin to God.

Forget not, O my soul,
The sacred Soil!

The Creator through
An eon's toil
Combined these two,
And said, 'it is enough,
My work is good;
In my own image—Man!
And in his mortal time,
In his own hand,
He holds his fate:
To build or ruin,
To plunder or create.'"

—J. Gladden Hutton.

1/Man. 2/Economic survey board
3/Reports. no. 15

THE SOILS OF MANITOBA

by

J. H. ELLIS

SOILS DEPARTMENT, UNIVERSITY OF MANITOBA

To that little group of tireless workers in the Manitoba Soils Survey, whose assistance in the field and in the laboratory has made possible the assembling of the information herein contained, this work is gratefully dedicated, with the hope that the love and respect for the Soils of Manitoba, which has been the incentive of these workers, will be shared in no small measure by the readers.

Published by

MANITOBA ECONOMIC SURVEY BOARD

C. B. DAVIDSON, M.A., *Director*
H. C. GRANT, PH.D., *Chief Research Associate*

September 15th, 1938

TABLE OF CONTENTS

APPENDICES

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS—Continued

LAND CLASSIFICATION MAPS

THE SOILS OF MANITOBA

CHAPTER 1.

INTRODUCTION

The living forms, whether of man or beast, or of fish or fowl, that can be supported by any region, all depend for their subsistence primarily upon the plants produced in field and forest, lake and stream, and these in the final analysis are determined by the productivity of the soil and climate.

By natural selection under virgin conditions, the soil produces the native plants best adapted to the local environment. The fertility of the soil and the climate determine the amount of vegetation that is produced, and in turn the amount of vegetative growth determines the animal life which can be supported. During life, the growing plants derive support from the contributions made to the soil by previous plant forms; at their death these plants contribute to the enrichment of the soil which produced them. Such contributions are used in turn by succeeding generations of life. For the maintenance of life through the ages since glaciation, nature evolved her own conservation policy. The living forms were maintained in equilibrium with their environment, and the soil, developed by life, continued as the supporter of life.

As a result of this natural conservation, rich acres of fertile prairie lands came into being in southern Manitoba. These were opened up in the pioneer days for the support of man, and now after half a century of settlement, it is imperative that Manitoba should take stock, and ascertain whether the agriculture and land-use policies which have been followed will maintain the productivity of the land, or whether the present development of the province has been done at the expense of soil and land exploitation.

The people of Manitoba have inherited a goodly heritage of natural resources. The wealth produced by the natural resources of the province is set forth by various writers in the companion reports on crops, livestock, forest, fish, game and water resources, etc. Manitobans may be justly proud of their natural resources, and of the progress made in the settlement and development of the province. Nevertheless, the progress to date is only the beginning of the story. It is vitally important that consideration be given to the question of the extent to which these resources will continue to be adequate for the support and maintenance of the province. If Manitoba is to be a prosperous and self-supporting province, an attempt must be made to maintain an equilibrium between the utilization and the conservation of the soil and land resources. When lands perish, the source of wealth vanishes.

During recent years an increasing interest in, and appreciation of, and concern for, the soils of Manitoba has become manifest. This treatise is presented to stimulate this interest; to outline a common concept of soils; to describe the factors responsible for the formation of Manitoba soils; to point out the characteristics of the soils of the different zones; to emphasize some of the major soil problems; and to bring into summary form the facts ascertained to date in connection with the soils of the province. It is submitted with the object of enabling the reader to know the essential facts about Manitoba soils and of pointing out the necessity of soil conservation.

By way of introduction and to orient the general reader to an appreciation of what may otherwise appear as uninteresting or irrelevant material in the text of this report, the following facts are submitted.

The total land area in Manitoba is approximately 148 million acres, but after 65 years of active settlement only one-seventh of this is organized into municipal units, and in this organized area 7¾ million acres only are listed as being under the plow at the present time. In other words, after approximately 65 years of active settlement, the organized territory has only one third of its soils under cultivation. This cultivated acreage constitutes only one-twentieth of the total land area in the province. Another pertinent fact is that the cultivated acreage in 1921 was listed as 9,022,738 acres and in 1936 as 7,789,920 acres. This indicates that over a million acres of land have gone out of cultivation during the intervening 16 years.

Settlement in Manitoba was commenced in 1812 by the Selkirk Colonists, but agricultural development really began on the prairie sections of the southern part of the province about 1875. Subsequent to this date settlement was active for many years. That is, there was an influx of pioneer settlers in the 70's, the 80's, and the 90's and later (and even again after 1918) land seekers travelled over the accessible portions of the province to select land for the establishment of settlements. Where soil conditions were unsuitable, land settlement either was not undertaken for reasons that were obvious to the land seekers, or, if agricultural settlement was attempted, it either failed to develop or was later abandoned.

After 65 years of settlement by this trial and error method, it is to be expected that agriculture will be found established where conditions were suitable, and where agriculture has not become established it is obvious that there must be some conditions or problems which hindered or prevented its establishment. These facts with regard to the utilization of land in Manitoba should be kept in mind by the reader. They point forcibly to the conclusions that the soils in Manitoba are not all suitable for agriculture, that soil problems exist, and that in considering an organized land-use policy, the soils of Manitoba must be considered, not only from the standpoint of agriculture, but also from the standpoint of forestry, wild life, water resources and public domain.

It should not be necessary further to emphasize the fact that the province as a whole has a vital interest in the conservation of the land. Not only does the present generation depend primarily for its support on the soils and the natural resources of the province, but future generations must be sustained from the same source. Both present and future civilization must be supported by the produce of the land.

The importance of mining is admitted. The exploitation of the products of the mine for use is the only policy that can be followed, but when the mines are exploited, the wealth is exhausted and the raw material cannot be renewed. There remain only holes in the ground and deserted communities.

On the other hand, the natural resources that are obtained from the land (whether crops, livestock, lumber, forestry, furs, water resources, etc.), can be used judiciously and, at the same time, conserved for the continued subsistence and development of the province. It is pointed out in the following pages that a wide variety of soil conditions exist. It is of vital importance that we recognize the factors which have determined the varied soil types and conditions, and adjust our land-use policies accordingly. In view of the available facts, land-use policies should be planned not for exploitation, but for maintenance and conservation. The land must remain.

Soils Defined:

Of the three major groups of natural objects used by man throughout the ages, i.e., soils, plants and animals, soils are perhaps the least understood by the average person. Hence before dealing more specifically with Manitoba soils, it may be advisable to present a few general facts about soils with the objective of ensuring a common concept of the subject.

Soils are natural objects which have developed at the surface of the earth as the result of the action of climate on the geological deposits that are under the influence of organic life. Soils differ from the geological material over which they lie. These differences are shown by the physical and chemical characteristics of the soil which may be enumerated under the headings of color, texture, structure, consistency, intrusions and concretions or products of soil weathering, reaction, etc. The sum of these characteristics determine the soil type (soil group).

In the process of soil formation, soils assume definite morphological characteristics that are mirrored or expressed in the cross-section through the portion affected which is known as the "soil profile." The soil profile is the soil unit. The upper portion of the soil profile (designated as the "A" horizon) is the zone of maximum weathering, and the maximum removal of the products of weathering. In grass-land soils, the "A" horizon also contains the maximum accumulation of organic deposition. Below the "A" horizon is the "B" horizon. This horizon is usually heavier in texture and more compact. In most soil types it is the zone of maximum concentration of the products of weathering,

which have moved downward from the "A" horizon. Underlying the "B" horizon is the "C" horizon which may be only slightly altered by the soil forming processes.

(These horizons are sometimes referred to as "surface soil," "sub-soil," and "sub-strata," but as the depth of the respeetive horizons differs in different soils, it is more descriptive and accurate to use the terms "A" horizon, "B" horizon and "C" horizon. The main soil horizons may be sub-divided for more detailed and accurate description, in which case they are designated as A_1, A_2, A_3; B_1, B_2, B_3; and C_1, etc.). (See fig. 1 and fig. 2).

When organic matter is added on the surface of the soil in nature, such as in the form of leaf mat or forest litter, it is designated as the A_0 layer.

When soils have an accumulation horizon of lime carbonate such an horizon is designated by the symbol C_a.

The horizon which is under the influence of ground water in poorly drained soils is known as the "glei" horizon, and when present it is designated by the symbol "G."

The soil horizons, designated respectively as "A," "B" and "C," are recognized by differences either in color, texture, structure, consistency and constitution, concretions and intrusions, or reaction.

The sum of the characteristics which are expressed in the different soil horizons enables the observer to ascertain the soil type. It is important that anyone who is working with soils should be able to recognize the more important morphological characteristics and that he should know the factors which are responsible for their formation. (See Appendices I and III).

Factors which Determine Soil Type:

The factors that determine soil type (or group) are:

(1) The climate, or the temperature and moisture within the soil;

(2) The vegetation, which determines the type of organic matter added to the soil;

(3) The parent material, or the geological deposits which determine the minerals on which the soil is formed, and in turn affect the texture, the water retention capacity, and the mineral reserve;

(4) The position in which the soil is found in relationship to the topography;

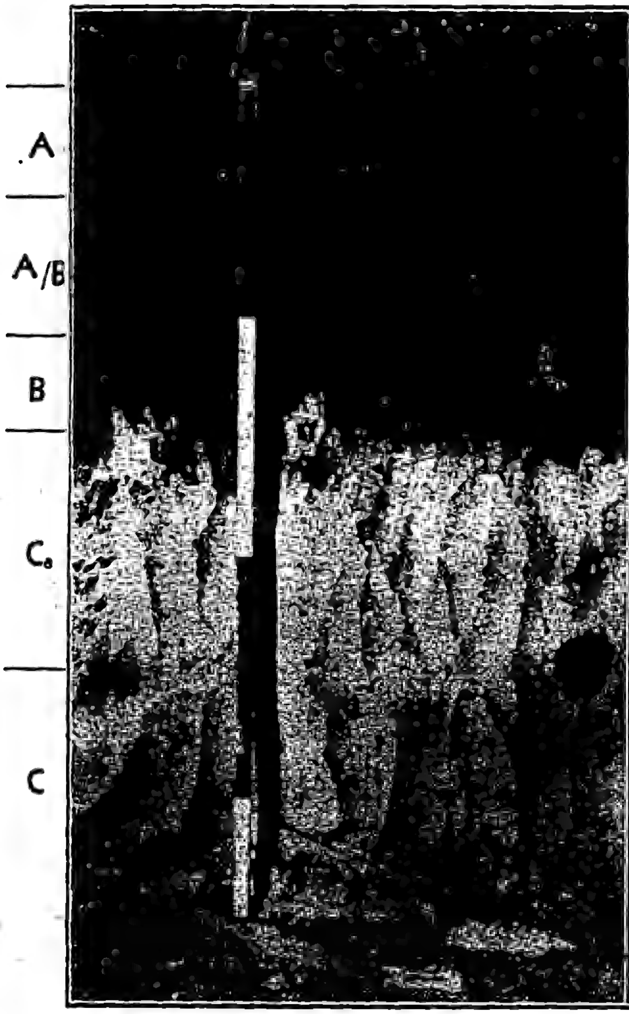
(5) The presence or absence of ground water within the soil profile;

(6) The age or length of time the soil has been under the influence of its environment; and

(7) In the case of cultivated soils—the modifying effects of culture or the work of man.

EXAMPLES OF SOIL PROFILES

FIGURE 1



Black earth soil profile showing sub-divisions into soil horizons:

A—Horizon black in color and finely granular.

A/B—Heavier horizon, black in color with weakly, cloddy structure.

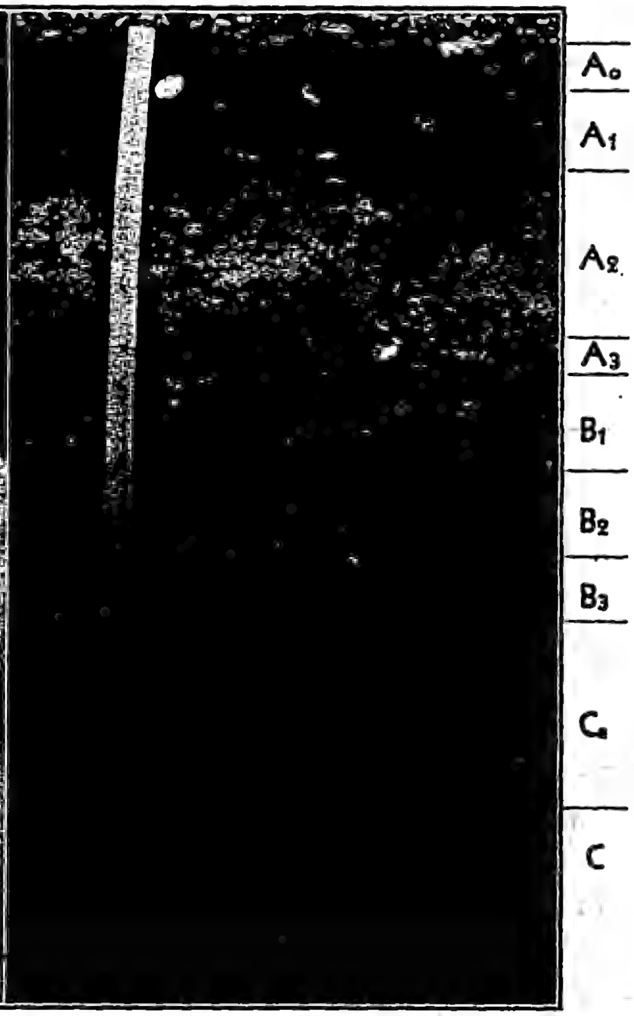
B—Drab-colored horizon.

Ca—Lime carbonate accumulation horizon.

C—The parent material only slightly altered.

The illustration shows gopher burrows as intrusions. Measuring rod is marked off in feet.

FIGURE 2



Grey wooded soil profile, showing sub-divisions into soil horizons:

A_0 —Leaf mat or forest litter.
A_1 —Black and crumb-like to finely granular.
A_2 —Whitish-grey, ash-like horizon with platy structure.
A_3 —Transition from A-B.
B_1 —Brown in color, heavier than A, with small nutty structure.
B_2 —Brown in color with larger nut aggregates.
B_3 —Transition horizon.
C_a —Horizon containing fleck-like concretions of lime carbonate.
C —Slightly altered parent material.

The illustration shows dark staining from decomposing minerals in the glacial drift.

These factors may be grouped into those which are regional and those which are local. That is, some of these factors are operative over large areas, whereas some may be quite local in effect. If the soils of Manitoba are examined in a traverse made from east to west, and from north to south, it is found that soils showing certain common characteristics extend as belts over wide areas. These belts are designated as regional or zonal soils. Within each of the soil zones, however, there are a number of soils in which local factors are dominant over the regional factors, with the result that local soils occur because of the differential expression of the determining factors enumerated above.

Because climate is the chief factor in determining the soil type, the mature well-drained soils of any region will have certain characteristics that are common to all the other well-drained soils of the climatic region in which they are found. This has given rise to the term "climatic" or "regional" or "zonal" soil types.

In each respective soil zone there are also different varieties of the regional soil type due to differences in parent material (or geological deposits).

Associated with the regional or zonal soils are a number of other soil types which may be designated as "intra-zonal" or "local" types, formed as a result of the dominance of local over regional factors. The most important of the local factors are the topography or relief, and the presence or absence of ground water.

In the transition areas between the soils of the grassland and the timbered regions, differences in soil type may occur because of differences in the vegetation under which the soils were formed. Thus islands of soils developed under woodland may be found associated with and markedly differing from the regional grassland soils. The differences in such cases are due to the modifying effect of the different types of vegetation on the "soil climate," as well as to differences in the kind of organic matter produced and added to the respective soils.

In the final analysis, however, it is the effect that these various factors have upon the soil climate (i.e., the temperature and moisture within the soil), which in turn controls the biological and chemical activities and thus determines the soil forming processes. The climate within the soil should not be confused with the climate of the atmosphere. Many different soil climates occur under a given regional climate.

CHAPTER 2.

FACTORS THAT HAVE AFFECTED MANITOBA SOILS

The factors which have contributed to the formation and development of the soils of Manitoba may be outlined under the following headings:

1. Parent material.
2. Relief.
3. Drainage.
4. Native vegetation and climate.
5. Age.
6. Culture.

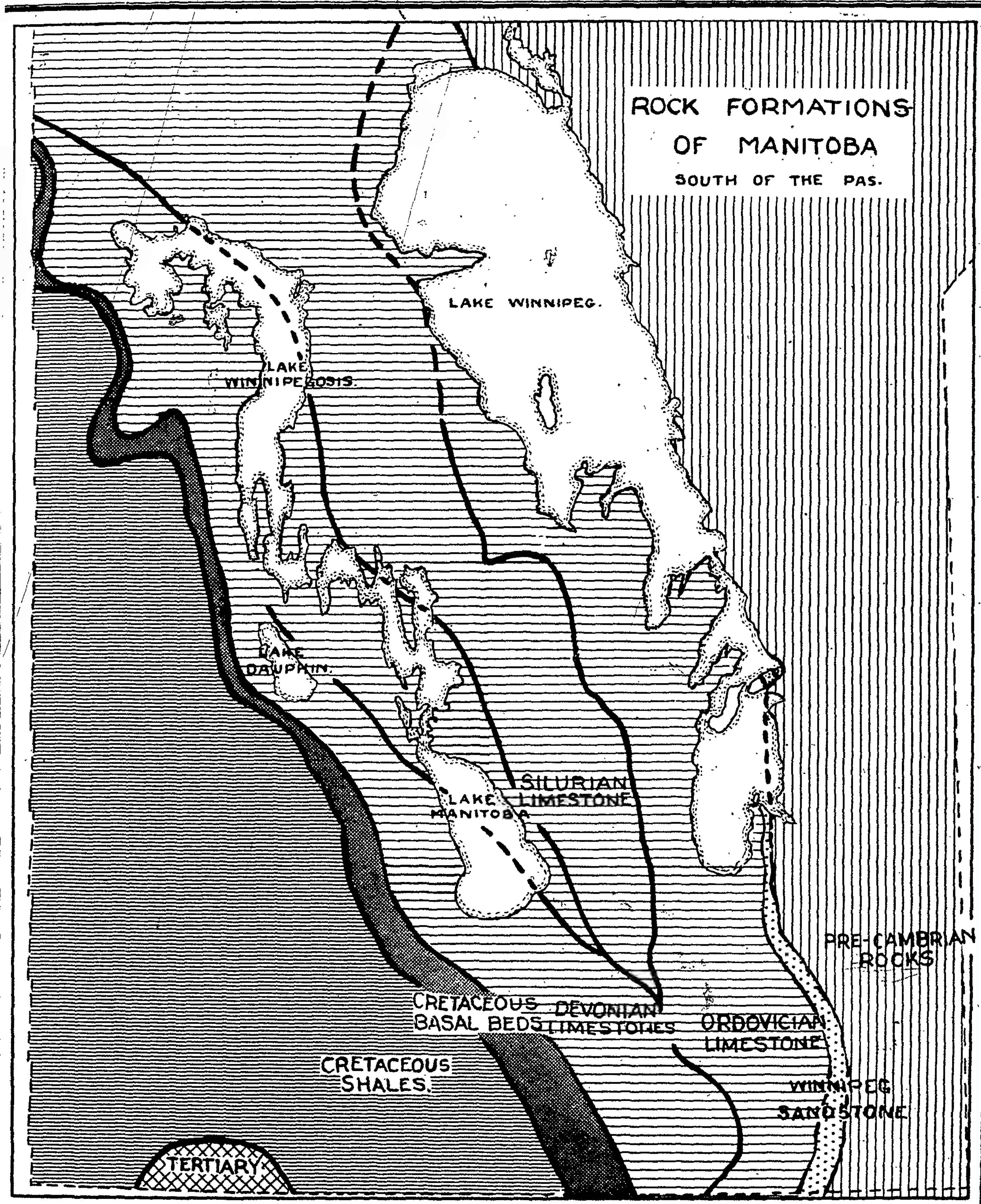


FIGURE 3
The rock formations of Manitoba

1. The Parent Material, or the Geological Deposits on which Manitoba Soils were Formed:

In the foregoing pages it has been stressed that soils are formed only on the geological deposits occurring at the surface of the earth, under the influence of organic life. Hence from a soil standpoint we are concerned only with the deposits which at present constitute part of the soil. It may be of interest, however, to review the kind and origin of the surface deposits on which Manitoba soils were formed.

The geology of Manitoba has been dealt with by Dr. DeLury in a separate report in this series. Hence with regard to the rock formations in Manitoba it is only necessary here to refer to fig. 3. This map here reproduced was supplied through the courtesy of the Department of Geology, University of Manitoba. It shows:

(1) An area of Pre-Cambrian rocks composed chiefly of granites, schists, and gneisses, occupying the region east and north of Lake Winnipeg, and forming part of the Laurentian Shield.

(2) An area of Palaeozoic lime-stones which include the Ordovician lime-stones in the east, the Silurian dolomitic lime-stones in the centre, and the Devonian lime-stones in its western portion. These rocks lie over the granites.

(3) An area of Cretaceous shales, etc., extending west of the Manitoba escarpment and superimposed over the lime-stones, and

(4) A small area of Tertiary rocks composed of shale and sandstone in the Turtle Mountain district.

These various rock formations supply the minerals which were transported during the ice age and laid down as the surface deposits by glacial action.

Deposits on Boulder Till, etc.:

During the glacial period a continental ice sheet moved from the region near James Bay across the granites, the lime-stones and the shales, carrying with it the loose and unconsolidated material, as well as the masses of rock plucked from the rock surfaces. These were carried far to the southward. During the melting and the recession of the ice sheet the rocks, gravel, sand, silt and clay contained in the ice were deposited (as a covering of unsorted materials) over the underlying rocks. This type of mineral deposit, known as boulder till (or glacial drift), forms the parent material of most of the soils west of the Manitoba escarpment.

In general the deposits of boulder till are relatively thick in the southern and western part of the province, and thinner in the Inter-lake region. In parts of the central portion of the Inter-lake region and in much of the eastern and northern portions of the province, areas occur that have little or no such

covering of till. Glaciation was so severe east of Lake Winnipeg that enormous areas of rocks were entirely denuded of covering and extensive areas of rock out-crop occur. Hence the lack of agricultural development in such portions of the province.

In the portion of the province where boulder till forms the surface deposits, it occurs both as till plain and as terminal moraines. The till plains are more or less undulating and contain occasional stone. The terminal and recessional moraines consist of chains of low hills of knob and kettle topography. They occur at intervals in the southern and western part of the province where the ice halted temporarily in its retreat as it was melting back from the south. The terminal moraines are characterized by rough topography, in which sharp hummocks are interspersed with numerous small lakes. The hummocks or hillocks are generally very stony. The moraines are in sharp contrast to the smoother topography of the till plains occurring between the successive morainic belts.

From the standpoint of the parent material of soils the boulder till deposits in Manitoba are of considerable significance. The ice sheet moved from the region near James Bay, across the granites, picking up granitic material. It then moved over the lime-stone region, picking up lime-stone and dolomite, and then moved over the softer Cretaceous shales where the drift was again diluted by the clay minerals from the Cretaceous rocks. This mixed till, containing minerals of mixed geological origin, was carried far to the southward by the earlier ice movements.

The boulder till deposits in Manitoba, however, show marked changes in the character of the drift in various parts of the province. For example, in the south-eastern portion of Manitoba a line is crossed near Beausejour, east of which the drift contains no lime-stone and the boulder till is of granitic origin. In the Inter-lake area the drift is generally of lime-stone origin and though it is sometimes mixed with granitic boulders, it is dominantly of lime-stone or dolomitic lime-stone origin. West and south of the Manitoba escarpment the surface drift deposits are quite variable. They may be composed largely of lime-stone; or lime-stone mixed with shale; or lime-stone, granite and shale; or in some cases the drift is composed almost entirely of shale and shale clay.

The soils that have developed on boulder till of mixed origin tend to be deeper than those developed on the high-lime drift. Soils developed on lime-stone drift are invariably shallow or have somewhat dwarfed profiles. In a few places, notably in the Manitou area, the ice sheet apparently removed all the surface covering and retreated, leaving the shale exposed. Subsequent advance of the ice sheet then eroded the shale, and as it retreated, drift composed largely of shale was left at the surface. The soils which subsequently developed on the shale drift are generally soils with deep profiles, low in lime.

Thus, except where rock out-crops occur in the eastern portion of Manitoba the rock formations are covered by boulder till. The boulder till usually contains a high percentage of lime because of the transportation by ice of the lime-stone drift from the Inter-lake region. Glacial drift, however, may be dominantly shale drift; it may be mixed lime-stone, granite and shale; it may be lime-stone and granite; or it may be of granite origin only. This accounts for the differences in the parent materials of soils in areas where the boulder till is at the surface.

Associated with the terminal moraines a further type of deposit sometimes occurs. The terminal moraines are formed where the ice melted away at the same rate that it advanced. As the waters from the melting ice flowed away through the morainic deposits of till, the mixed drift material was sorted by water. Where this melting was rapid, the swiftly moving waters separated the drift into different textures over the surface, away from the ice, so that at the present time there may be found a sequence of textures; first the very stony morainic hills; next, cobbly and coarse gravelly outwash; and finally outwash plains of sand, which are coarser nearer to the moraine and finer as the plain extends away from the moraine. These outwash plains are local in area, but they are exceedingly important where they occur, as they are responsible for local areas of coarse textured or skeleton-like sub-marginal soils.

These outwash plains, however, are not widespread in Manitoba, which indicates that the melting of the ice at the terminal moraines did not always produce torrential streams.

Deposits Over Boulder Till:

As the ice retreated, the melting waters, augmented by the drainage waters from the west and south, flowed back against the ice sheet and covered the lower surface levels. Thus, due to the blocking of the outlets by the ice in the north and east, several glacial lakes were formed in which sediments carried into these lakes by drainage waters were deposited over the boulder till. These deposits gave rise to the stone-free areas of sand, silt and clay, which cover the boulder till over a large part of the province.

The topography of these water-laid deposits is usually smoother than that of the till plains, and in the case of the clay deposits, invariably flat. Where large areas of sand were deposited as water-laid sediments, however, they may have given rise to sand dunes, which were formed by wind action before vegetation had progressed sufficiently to prevent the movement of sand.

As the ice retreated from the south-western part of the province, the first glacial lake to be formed occurred in the Souris basin in south-western Manitoba. Waters from the drainage of the Souris, the Qu'Appelle, the Assiniboine and the Saskatchewan rivers flowed into the Souris basin, carrying in enormous quantities of sediment. This glacial Lake Souris outflowed at Bunclody and Heaslip through Lang's Valley and the Pembina Channel.

As the ice retreated back still further, the glacial Lake Souris extended eastward over the Brandon district, so that lacustrine sediments are now found extending from Kenton to the Brandon Hills.

As the ice retreated from the Manitoba escarpment, the waters followed the ice and formed what is known as glacial Lake Agassiz, in the first steppe.

The waters of the glacial lakes have affected profoundly the surface deposits in Manitoba. In south-western Manitoba, the boulder till is covered by lacustrine sediments in the area which may be roughly bounded by Carroll, Napinka, Dalny, Pierson, Pipestone, Virden, Harding, Rivers and Forrest. The western portion of this area represents the earlier stage of glacial Lake Souris, and the eastern portion the later stage.

The first steppe has been profoundly modified by the sediments in Lake Agassiz. The western shore of Lake Agassiz is bounded approximately by Thornhill, northward along the east side of the Pembina Hills to just south of Treherne; it then turns westward along the north side of the Tiger Hills and the Brandon Hills, where the lacustrine deposits merge into those of Lake Souris. North of Brandon the lacustrine deposits of Lake Souris merge into those of Lake Agassiz, but the shore of Lake Agassiz can be traced from Forrest, Brookdale and Neepawa, and then northward along the east side of the Riding Mountains, the Duck Mountains, and the Porcupine Hills.

The surface deposits which became the parent material of the soils in the bed of Lake Agassiz can be divided into:

(1) The clay deposits of the Red River Valley,

(2) The lighter textured and sandy deposits of the Assiniboine delta,

(3) The gravelly beaches, wave cut terraces, and the high lime modified drift between the escarpment and Lake Manitoba, and

(4) The mixed lacustrine deposits and modified till of the Inter-lake area.

The areas of the glacial lakes are shown in fig. 4. This map was compiled from observations made during the progress of the Manitoba Soil Survey, added to the geological surface map prepared by W. A. Johnston.[1]

The glacial lakes in Manitoba have been dealt with in an excellent manner by Upham,[2] Antevs,[3] and Johnston,[4] and for further details the reader is referred to the works of these authors.

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[1] W. A. Johnston, Geological Survey Ottawa Memoir No. 174, (1934).

[2] Warren Upham: Glacial Lake Agassiz in Manitoba, Geological and Natural History Survey of Canada, (1890).

[3] E. Antevs: Geological Survey, Ottawa, Memoir No. 168, (1931).

[4] W. A. Johnston: Geological Survey, Ottawa, Memoir No. 174, (1934).

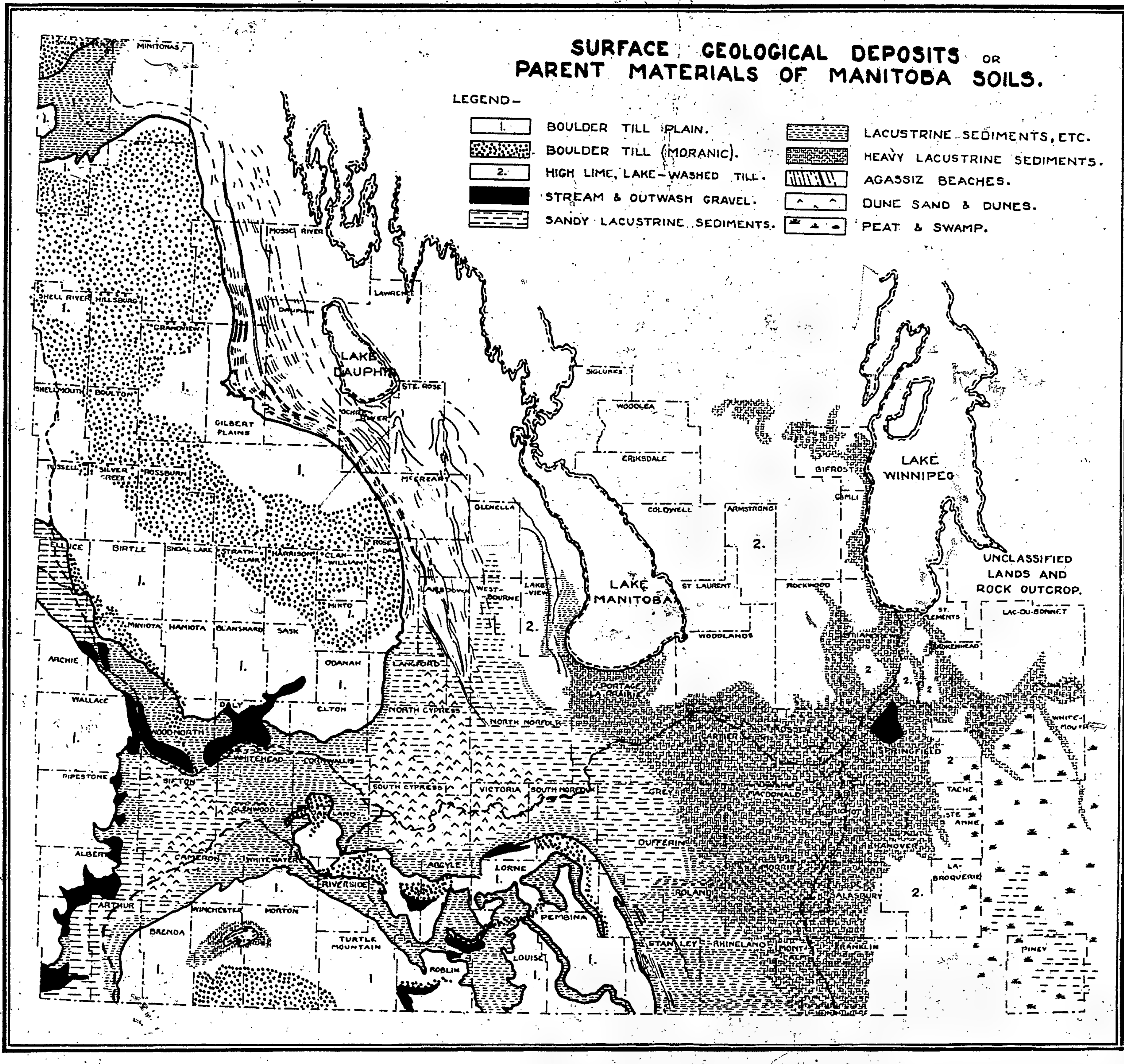


FIGURE 4
The surface geological deposits or the parent material of Manitoba soils.

During the progress of the Manitoba Soil Survey it was found that considerable areas occurred south of the Tiger Hills where the waters from the melting ice and from the glacial lakes flowed southward, or were ponded over the drift, leaving considerable areas of lacustrine sediments overlying the boulder till in the south central portion of the province.

Lacustrine sediments also occur along the east side of Lake Winnipeg and in the country north of The Pas. These latter areas, however, are not so well known, and at present their extent cannot be delineated.

During and subsequent to the glacial lake stage, the glacial drift underwent erosion. Valleys were cut by stream channels and the water-carried materials were deposited as sediments in the lakes. With the drying up of the lakes, erosion continued, and in some cases the drift and the lacustrine sediments were buried under the flood plain deposits and alluvium.

These surface geological deposits, fig. 4, which form the parent material of Manitoba soils, insofar as they have been studied to date, include in addition to the boulder till and the modified drift and outwash material (which are the largest occurring deposits west of the Manitoba escarpment) the sandy, light-textured deposits in the basin of Lake Souris in south-western Manitoba; the sandy deposits of the Assiniboine delta between Portage la Prairie, Plumas, Neepawa, Brandon and the Tiger Hills; the medium to medium-heavy textured lacustrine deposits which extend from Kenton to the Brandon Hills, and the local areas of similar material in the drift area south of the Tiger Hills; the clay deposits of the Red River Valley and the Arborg district; the gravelly and sandy beaches along the west shore of glacial Lake Agassiz, especially between the Manitoba escarpment and Lakes Manitoba and Winnipegosis; and the water-worked, high-lime drift and modified drift of the Inter-lake and West Lake region. There are also local areas of stream outwash, flood plain overwash, and alluvium.

Local areas of lacustrine material and modified drift also occur in the Dauphin and Swan River districts, where bays of Lake Agassiz extended into the escarpment. In addition, reference should be made to the extensive areas of rock outcrop, with smaller areas of drift, lacustrine and stream deposits east of Lake Winnipeg.

Reference also should be made to the areas of organic deposits or peat. In eastern Manitoba, in the Inter-lake area and in northern Manitoba, both large and small areas of flat topography occur. In many cases, small lakes and ponds became stagnant and were filled in by vegetative growths, so that at the present time there are considerable areas of peat which were laid down as organic deposits. Thus, in addition to the mineral deposits, there are also appreciable areas of organic deposits. It is on these varied geological surface deposits that the soils of Manitoba were formed.

(The relationship of parent material to soil texture, water retention capacity, and lime and mineral reserve is discussed in Appendix II.)

2. Relief.

In Manitoba, relief is an important factor in soil formation. This is due to the effect of relief on the soil climate (or the temperature and moisture conditions within the soil). Relief may be of three degrees: Macro-relief; meso-relief, and micro-relief.

I. Macro-Relief: This term refers to the chief features of relief, such as hills and valleys, where differences in altitude are very marked.

II. Meso-Relief: This term may be used to describe the noticeable features of relief which are not so well expressed as in macro-relief. That is, the terrain may show rolling to undulating topography with knolls, slopes, and depressions, with local differences in elevation that may affect to a considerable degree the amount of water which penetrates into the soil in each of the different topographical positions.

III. Micro-Relief: This term may be used to describe small, almost imperceptible variations in level which occur on otherwise smooth plains. No land is absolutely level. Low hummocks may be present, and shallow depressions which hold water after a rain may be observed on what may otherwise appear to be a smooth, level plain. These differences in relief result in differences in soil, because differences in the position of the soil in relation to relief result in differences in local soil climate.

Relief may be direct or reverse. That is, the land surface may drop below the general level, in which case the relief is direct, or, on the other hand, the land may rise above the general level, in which case the relief is reverse.

Two different aspects of relief should be noted in connection with the effect of relief on the soils of Manitoba. The first is the differences in altitude, and the second is differences in topography.

A contour map prepared from the topographical sheets of the Department of the Interior is shown in fig. 5. The contour lines on this map show that Manitoba can be divided into two main regions: The first is the second steppe west of the Manitoba escarpment, and the second is the first steppe east of the escarpment.

A. THE SECOND STEPPE:

The land west of the escarpment lies at a higher altitude than the land east of the escarpment. On the second steppe, which lies above the 1,300-1,400-foot contour, there are two critical lines, the 1,900 and the 1,550-foot contours. Above the 1,900-foot contour lines in the Turtle and the Riding Mountains, the land rises from 1,900 to between 2,400 and 2,500 feet in altitude. The altitude of the portion above the 1,900-foot contour is sufficiently high to profoundly affect the local climate, because the soils above the 1,900-foot contour are grey-wooded soils, formed under the influence of timber. Hence

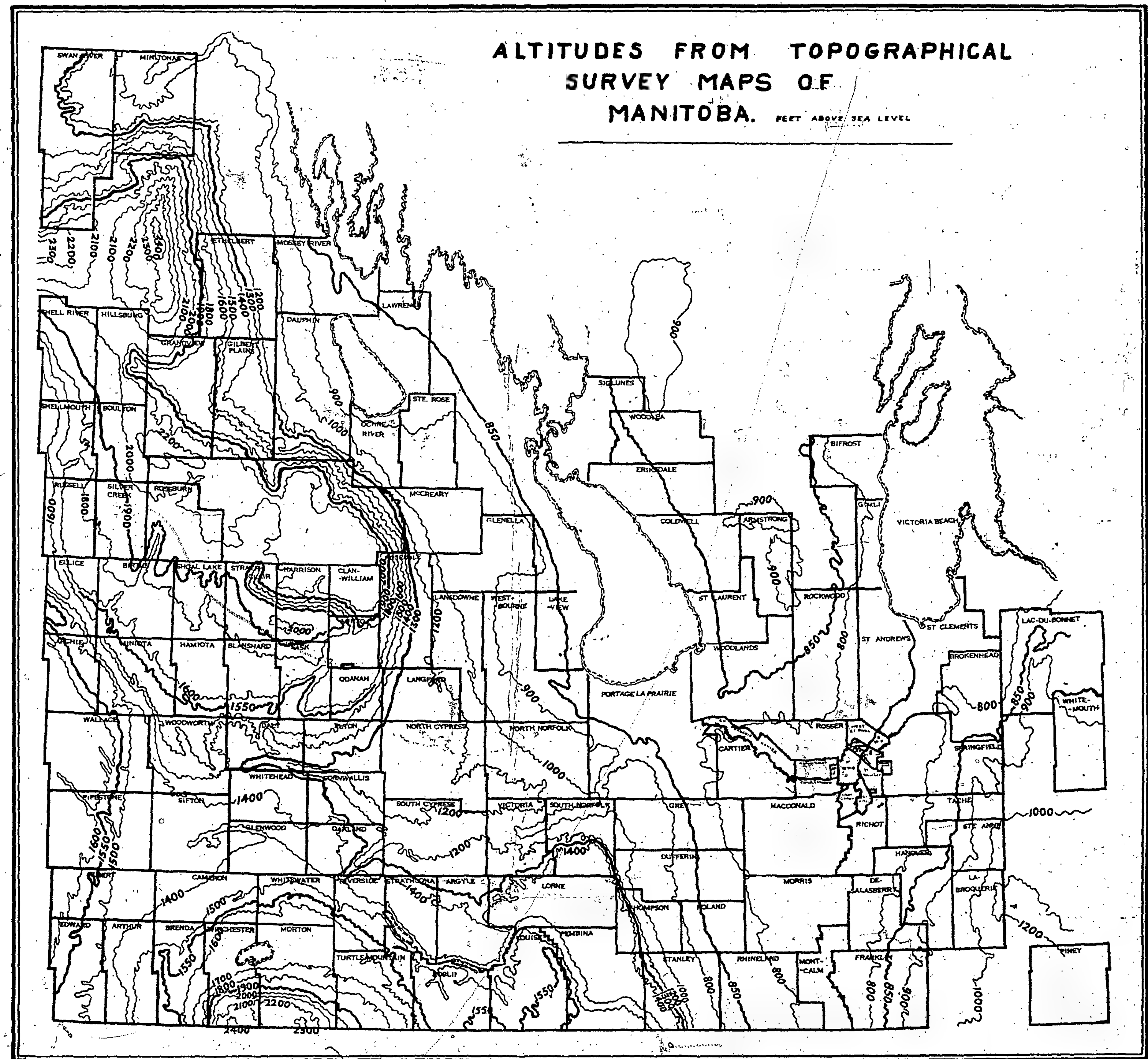


FIGURE 5
Altitudes from Topographical Survey Maps of Manitoba.

the 1,900-foot contour may be taken approximately as the original timber line in the western and southern part of Manitoba. It should be further noted that at these higher altitudes, the terrain generally presents a roughly undulating and hilly topography, more or less morainic in type. Sharp hills and hummocks with frequent depressions often containing small lakes or ponds are common. The local climate here is cooler and more humid. In other words, it has a higher Precipitation-Effectivity and a lower Temperature-Efficiency than at the lower altitudes adjacent.

From the 1,900-foot to the 1,550-foot contour the terrain in the second steppe occurs as an undulating plain of boulder till with occasional terminal moraines. The terminal moraines which occupy only portions of the area are shown in fig. 4. They have a knob and kettle topography and numerous small lakes. The till plain area between the moraines varies from smoothly to roughly undulating, and is characterized by numerous depressions with meadow soils and saline soils.

Below the 1,550-foot contour in south-western Manitoba, the terrain has been determined by the bed of glacial Lake Souris. This lake basin presents a smooth, almost level topography, except at a few places where the sand has been blown up into dunes. Between the sand dunes and Brandon, the smooth terrain has been eroded by stream action and now presents a somewhat rolling aspect. Erosion is markedly affecting the area from Brandon and Oak Lake northward to Kenton.

B. THE FIRST OR EASTERN STEPPE:

The first steppe, which is bordered on the west by the 1,300-1,400-foot contour, in general, is lower in altitude than the second steppe; the topography is much smoother and in many cases the topography is almost flat. A critical altitude exists within the first steppe, namely, the 850-foot contour. Below the 850-foot contour lie the heavy clays deposited in Lake Agassiz, which are characterized by a flat to smooth topography. Between the 850 and the 1,300-1,400-foot contour the terrain immediately east of the escarpment may be divided into three sub-divisions:

(a) *The First Sub-Division:* The first sub-division consists of the land lying east of the Pembina Hills, in the Thompson and Stanley Municipalities. Here the land falls fairly smoothly eastward and the surface material is beach deposits, lake terraces, and stream over-wash.

(b) *The Second Sub-Division:* The second sub-division includes the areas from Carman, Gladstone and Plumas, westward to Neepawa and Brandon, and southward to the Tiger Hills. The land surface in this area was determined by the light-textured deposits of the Assiniboine delta when the waters of Lake Agassiz covered this area. These sandy deposits which make a gradual approach from the first to the second steppe, present a smooth topography in the north, west, east and south. In the central portion of the Assiniboine delta,

however, the sand deposits have been blown into dunes, so that the Spruce Reserve in the centre of this area is characterized by dune topography in sharp contrast to the smooth, almost level, plains around the outer portions of the delta.

(c) *The Third Sub-Division:* The third sub-division extends from Neepawa northward to Swan River, between the 850-foot contour and the 1,300-1,400-foot contour. Here the terrain is characterized by a series of gravel beaches which were formed at successive stages by the waters of Lake Agassiz. These numerous beaches run crosswise of the slope from the Riding and Duck Mountains to Lake Manitoba and Lake Winnipegosis. These beaches have profoundly affected the soil in this area, because they prevent the normal drainage from the mountains reaching the lakes. This is emphasized, if it is noted that the fall from the height of land on the Riding Mountain (with a height of over 2,200-2,400 feet) is eastward to Lake Manitoba at an altitude of 814 feet. Numerous streams issue east from the Riding Mountains, but there are no important streams entering into Lake Manitoba along its western side north of the Whitemud in the southwest corner. The terrain in this lake beach area presents a recurring series of gravel beaches running generally from the north-northwest and south-southeast over a surface that has a marked eastern slope. On the western side of these beaches there is generally a strip of shallow peat or muck, and on the eastern side of the beaches there is generally a narrow strip of sand. East of the sand, which is shore deposit, there occurs the lake-washed drift with marked micro-relief features. This sequence keeps on recurring more or less all the way from the 1,300-1,400-foot contour to the 850-foot contour line and it also occurs to some extent east of this line, to the shores of Lakes Manitoba and Winnipegosis.

In the Inter-lake area the 850-foot contour again becomes a critical altitude, because above this line the terrain consists largely of an outcrop of lime-stone and dolomitic lime-stone rocks, which rise gradually to the 900 and 950-foot contours.

East of the Red River Valley the 850-foot contour again becomes a critical point, because this line marks approximately the eastern limit of the heavy clay deposits and the eastern limits of the flat Red River Valley plain.

The above notations on relief may be summarized as follows: The surface of the organized portion of Manitoba may be divided into two major divisions: (1) the first steppe east of the Manitoba escarpment, and (2) the second steppe west of the escarpment.

1. The eastern division or the first steppe may be divided topographically into:

   (a) The area between the 1,300-1,400-foot contour and the 850-foot contour. This may again be subdivided from south to north into:

i. The lake terrace, beaches, shore deposits and stream outwash, of more or less smooth topography, sloping eastward in the area immediately east of the Pembina Hills.

ii. The Assiniboine delta from Carman to Neepawa, and west to Brandon, which is characterized by smooth almost level topography in the north, west and east, and by sand dunes in the centre.

iii. The lake terraces and beaches north of Neepawa and east of the Riding and Duck Mountains, with micro-relief and often poorly drained.

(b) The smooth flat Red River plain below the 850-foot contour.

(c) The flat to very gently undulating water-worked boulder till and rock outcrop in the Inter-lake area.

(d) The smoothly undulating area east of the Red River which grades into the granitic rock outcrop area between Whitemouth and the Ontario border, and

(e) The rough rock outcrop area east of Lake Winnipeg.

2 The western division or the second steppe may be divided into:

(a) The smooth topography of the Souris basin below the 1,550-foot contour.

(b) The undulating till plain in south central Manitoba between the 1,550-foot contour and the 1,900-foot contour, and the till plain between the Riding Mountains and the Souris basin. This latter plain has a south westward exposure.

(c) The morainic topography in the Turtle, Riding, Duck and Porcupine Mountains above the 1,900-foot contour, which is under forest, and under which grey-wooded soils are found.

The general slope or fall and exposure of the areas briefly described above may be readily seen by referring to the Contour Map shown as fig. 5, and further illustrated by the cross-sections which are shown as fig. 6. The figures in these cross-sections illustrate the slope, the altitudes, the vegetation zones, the surface geological deposits, and the underlying rocks.

In connection with the effects of altitude and slope on the soil climate in Manitoba a few points should be emphasized. The lower altitudes of the Red River Valley, the Assiniboine delta, and the plains of the Souris basin, result in a somewhat warmer soil climate compared to that of the higher altitudes occupied by the boulder till of the second steppe. Fig. 5 and the Contour Map, fig. 6, also bring out the fact that the land west and south of the Riding Mountains falls westward and southward. As air currents in Manitoba move from the west to the east, the air has to rise to pass over the Riding Mountains. When this occurs, the air cools, with the result that there is a cooler climate on the west and southwest of this mountain. As the air falls eastward over the escarpment to the lower altitudes, the air warms with

decreasing altitude, with the result that there is a higher Temperature-Efficiency immediately east of the escarpment. Thus, the soils in the Red River Valley, the Assiniboine delta, and the beach area east of the escarpment are warmer than at the same latitudes in the western part of the province. In local areas, increased air temperature is off-set in the soil by the cooling effect of increased moisture, caused by run-off from the higher lands.

Throughout the first steppe large local areas of impeded drainage and swamping occur, causing a cooler local soil climate such as is found in meadow and peat soils.

The foregoing observations with regard to the effect of relief should be kept in mind in interpreting the vegetation and regional soil belts, and in any generalized physiographic observations on Manitoba soils.

Relief also is a fundamental factor in the determination of some local soils. A soil in the normal well-drained position will be determined chiefly by the regional climate. Local variations in topographical position, however, such as knolls, slopes and depressions, will result in soil climates which differ from the normal regional soils. For example, if the precipitation on a given section of land is 18 inches per year, the soil on the knolls will receive 18 inches less the amount which runs off. Hence the soil on the knolls will have a locally arid climate in comparison with the normal soils. Such soils may be designated as being "locally arid associates." The extent of this local aridity will be determined by the amount of water penetrating into the soil and the amount of run-off.

On the other hand, the soils of the depressions, in the example given, will receive 18 inches of precipitation plus the amount of water which runs off from the adjacent higher lands. Hence more water will penetrate into the soils in the lower position, and such soils may be termed "locally humid associates," because they have a more humid soil climate than the normal soils. (See fig. 7).

This may be seen emphasized in undulating topography, if a cross-section is made from one knoll through the depression to another knoll. The soils on the knolls in the virgin condition will be found to be much more shallow than the normal soils, and the depth of the soil profile will be seen to increase gradually down the slope to the deeper than normal soils at the foot of the slope. This difference from the top of the knolls or hills to the centre of the depressions may be of sufficient degree to show a marked effect on soil climate, so that different soil types may be found in the different topographical positions. This is shown strikingly in the northern black earth soil region in Manitoba (Soil Zone 3). The normal soils in the northern black earth region developed on boulder till show a black "A" horizon and a brown "B" horizon, underlain by a horizon speckled with lime carbonate (the depth of the black and brown horizons together being about 16 or 20 inches). This soil is representative of the normal soils occurring in the normal well-drained position. At the top of the knolls, however (that is, in the locally arid position), black

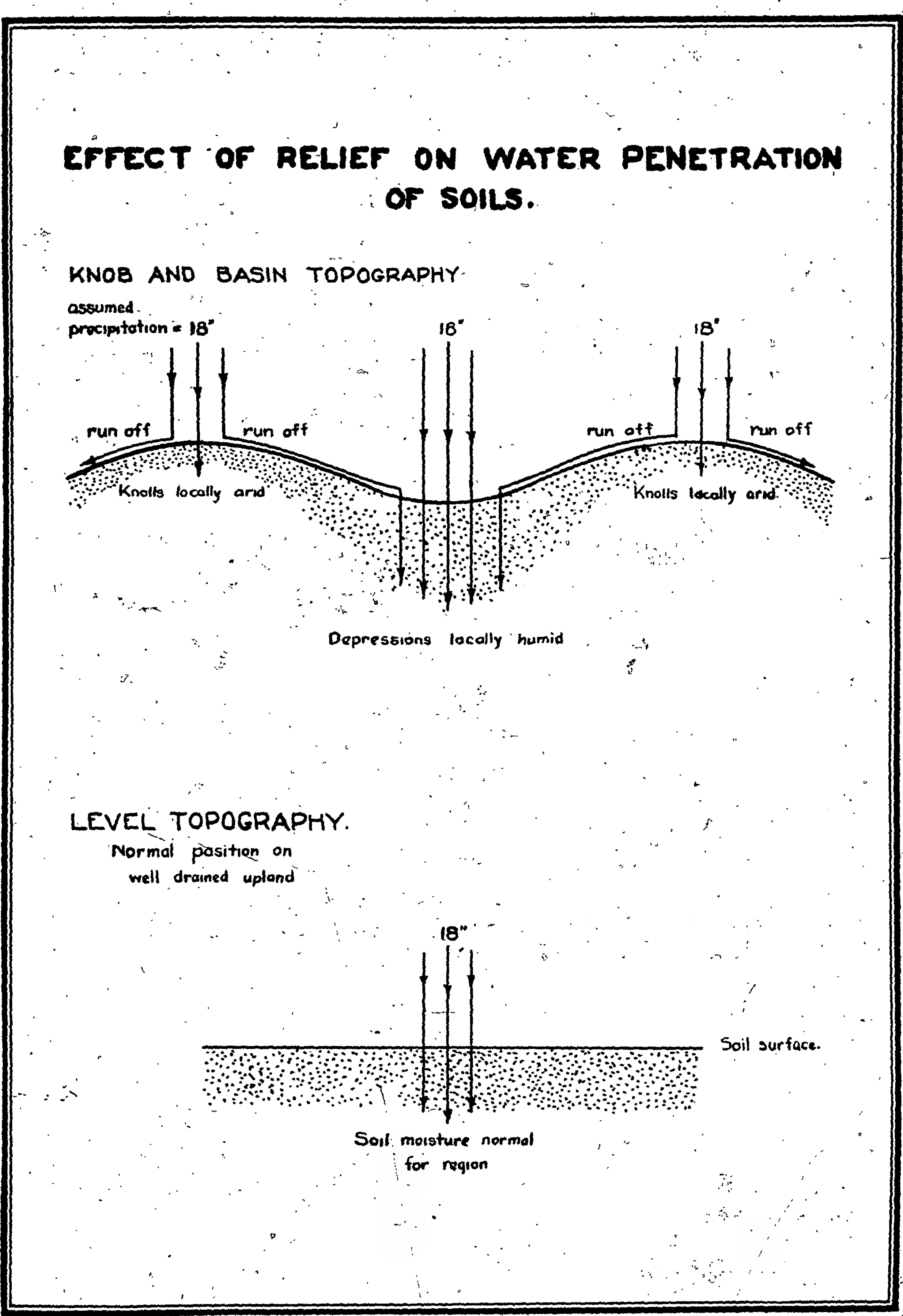


FIGURE 7
The effect of relief on water penetration in soils.

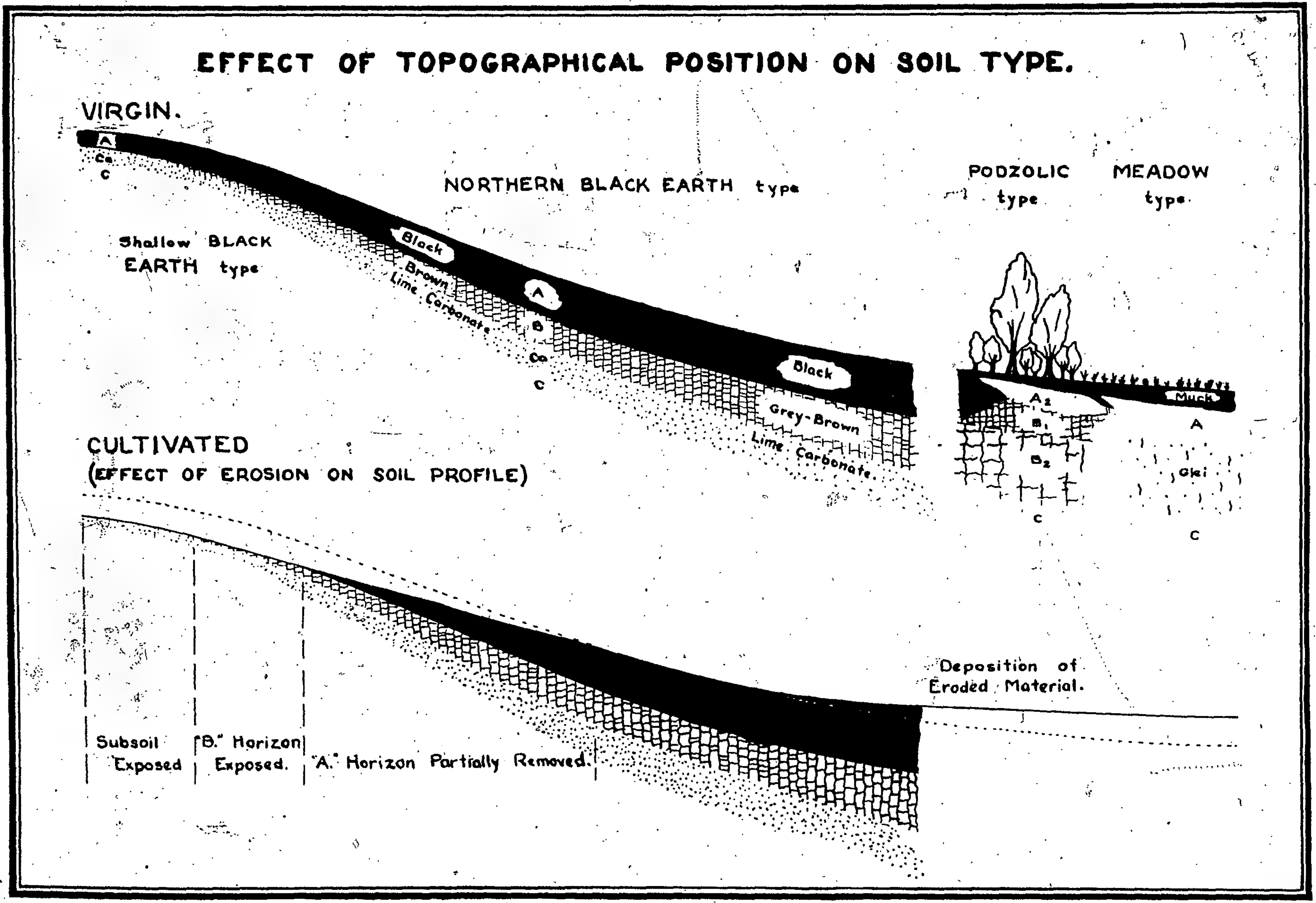


FIGURE 8
The effect of topographical position on soil type.

earth soils have developed. The soil on the knolls here shows a shallow black "A" horizon resting on a horizon of lime carbonate without any brown "B" horizon. At the foot of the slopes in the northern black earth region the soils show a black "A" horizon, a "B" horizon which instead of being brown is olive grey drab, and the lime carbonate may be at 30 to 36 inches below the surface instead of at 18 or 20 inches. In the centre of the depression a swamp podzol soil often occurs under swale grasses, with a deep, grey A_2 layer; a tough, heavy, waxy, dark colored "B" horizon; and an iron stained glei horizon without an accumulation of lime carbonate. (See fig. 8).

Thus, black earths, northern black earths, and either meadow soils or swamp podzols, may exist within a few rods of each other on exactly the same parent material, occurring respectively in the locally arid, the normal and the locally humid soils under the same atmospheric climate, but with different soil climates. This example shows the effect of relief on the formation of local soil types.

This difference in soil climate is seen also in the vegetation which occurs naturally on the locally arid, the normal and the locally humid positions. The above illustration indicates that wide differences may occur where the local differences in relief are marked, and where relief may be described as meso-relief. Differences in soil also may be recognized due to relief even where the slight differences in elevation are termed micro-relief. The soil climate differences noted above are due chiefly to differences in the amounts of water which penetrate into the soil, and, to the exposure or direction of the slope with resulting variations in heat absorption.

A further effect of relief on soils is brought about by run-off. During times of heavy rains and during run-off from the melting snows, surface soil may be removed by water erosion from the higher positions and deposited in the lower positions. In the higher positions the knolls tend to become more shallow by the removal of the surface material, and the soils at the foot of the slopes become deeper through the accumulation of the material eroded from the higher levels. Under cultivation, wind is also a powerful factor in removing soil from the surface in the higher positions. These forces, causing the removal of surface soil, develop what is known as truncated soil profiles.

3. Drainage

The presence or absence of ground water has played an important role in controlling the type of soil forming processes in Manitoba soils. Soil drainage may be considered from the standpoint of "external" and "internal." External drainage is controlled by relief or topography, and by the vegetative cover. The more run-off, the less water there is penetrating into the soil, and, consequently, the steeper the slopes the greater the surface run-off. Vegetation plays an important part in affecting run-off. Under timber the run-off is retarded so that the soils on the hills and slopes are more humid than they would be under grassland. The removal of the vegetation by fire or culture

increases the run-off, and thus predisposes to drier soil conditions. The increased degree of dryness that results is determined by the increased degree of run-off.

The internal drainage of soils is affected by the soil texture, structure and porosity; by the presence or absence of impervious strata and rock; by the rise of ground water; and by the position of the soil in relation to the surrounding areas. In clay soils with flat topography, percolation of water is retarded or slowed down, and such soils are more humid than adjacent light textured soils. In light textured or sandy soils, precipitation penetrates more rapidly and to a greater depth, resulting in drier soils and deeper soil profiles.

Impeded drainage is an important factor over considerable soil areas in Manitoba. Large areas of soil with impeded drainage are common east of the Manitoba escarpment, in what has been described as the "first steppe." The country lying west of lake Manitoba and lake Winnipegosis is characterized by considerable areas of soils swamped by run-off waters. In many places in the Inter-lake area, a thin covering of till only is found over the horizontally bedded lime-stone; as a result, in wet seasons the soils in the lower positions in this area contain ground water which rises upwards into the soil profile, thus markedly affecting the soil forming processes. Throughout the "Manitoba Lowlands" and in northern Manitoba, large areas of peat, swamp and meadow soils are common owing to the flat topography and impeded drainage. In southeastern Manitoba large areas of swamp and peat also occur because of run-off and the rise of ground water which flows in from the higher terrain along the Manitoba-Ontario border.

The soils of heavy texture on the flat topography of the relatively lower altitudes of the Red River Valley, especially in the southwestern and eastern portion, are subject to periodic flooding by run-off from the adjacent higher lands, thus resulting in extensive local drainage problems.

The sandy deposits of the Assiniboine delta and of the lake Souris basin, both of which lie below the level of the adjacent boulder clay areas, are characterized by the presence of ground water, although the surface soils may have rapid surface drainage because of the relatively light textures and high porosity. Throughout the Assiniboine delta, ground water may be found at from 12 to 20 feet; in the Souris basin the sandy soils may contain ground water at from 6 to 8 feet or less. In both these areas, ground water plays an important part in supplying water to tap-rooted plants, so that while the surface light textured soils may tend to be droughty, the subsoils tend to be moist and the depressed positions tend to be wet.

When impeded drainage or swamping from excessive amounts of run-off water results in the presence of ground water within the soil profile, the soil forming processes are affected to a marked degree. Under free drainage, oxidation of the minerals takes place, and this is reflected in the subsoil colors. Brown, buff, drab and straw colored subsoils indicate good internal drainage.

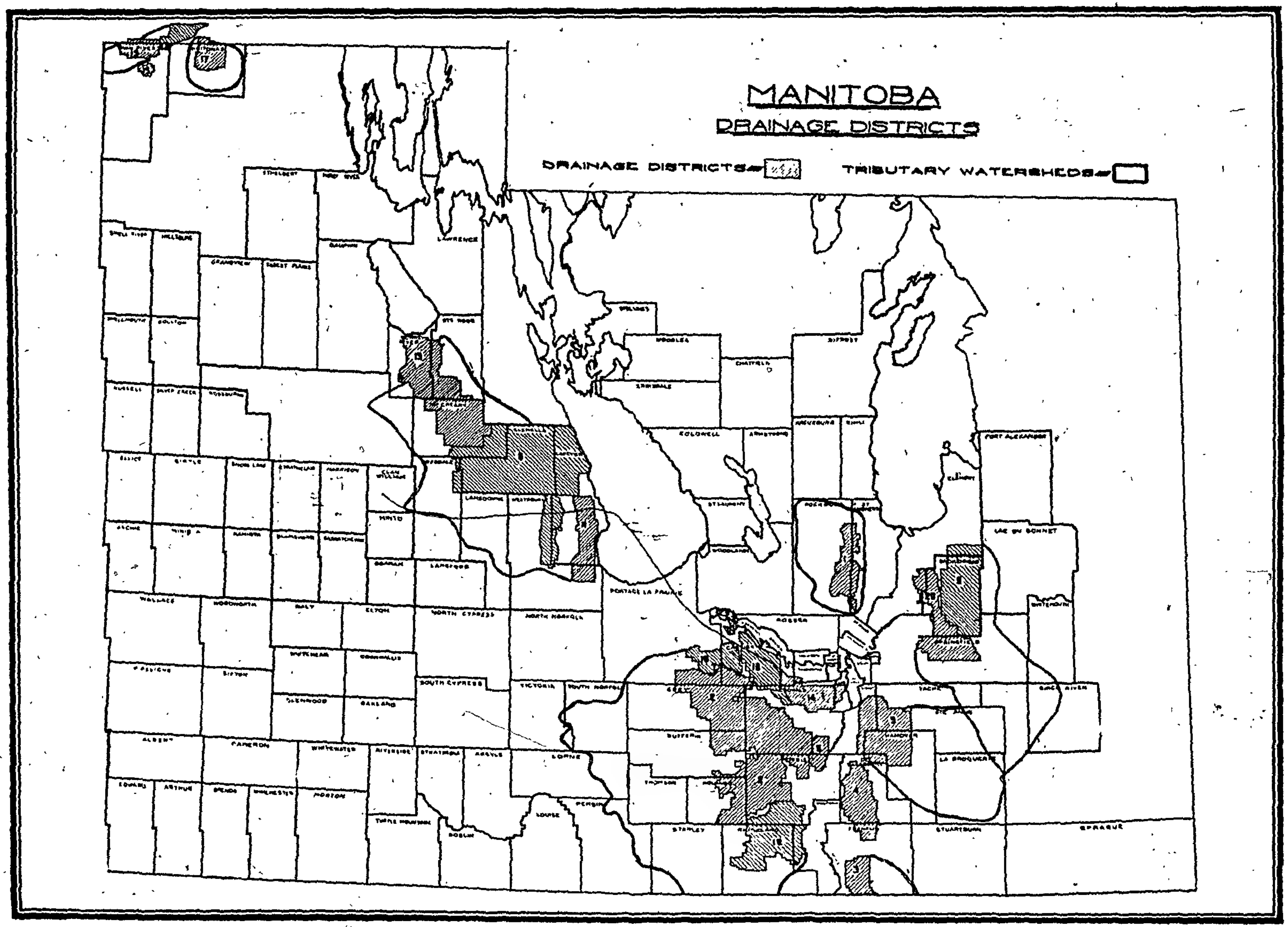


Figure 9
The drainage districts in Manitoba

On the other hand, wet subsoils are characterized by reduction rather than oxidation processes, and this is reflected in the color of the subsoils, which show blue, blue-grey, grey, and mottled colors. The presence of limonite (or iron) concretions which are reddish brown in color, occurring as specks in the dead root channels, or as specks, eyes, or iron stained blotches in grey or blue colored subsoil, indicates prevailing wet subsoil conditions. Thus, if the soil is examined even in a dry period, the effect of ground water may be observed and the necessity, or otherwise, of drainage can be ascertained.

A further observation should be made with regard to the types of swamping by ground water. The soils resulting from the action of periodic swamping may be either non-saline meadow soils, swamp podzols, etc., or they may be saline soils. If the swamping is caused by non-saline waters, or if it is due to run-off waters which keep the soils moist but in which the surplus waters gradually seep away, the soil may not show any salinity.

On the other hand, the rise of ground waters, the inflow of run-off waters containing soluble salts, or the periodic swamping of soils with arrested drainage, results in a concentration of salts in the soil so that saline or alkaline soils develop.

It has been noted above that peat deposits occur over considerable areas in the more humid parts of the province. These deposits were formed by the deposition of hydrophytic vegetation which grew up in water. A sequence of development from pond lilies, reeds, swamp grasses and sedges, converted the ponds or shallow stagnant lakes into land surfaces of organic deposits. These fen type peats, occupying the lower positions, are also under the influence of ground water. Northward in the wooded region the fen peats give place to tamarack swamps, and to tamarack and moss peats.

The above can be summarized by stating that the presence of ground water in many of the soils of Manitoba results in the development of certain local soil types, many of which occur over large areas, but particularly east of the Manitoba escarpment. In the wooded regions the soils developed under the influence of ground water include meadow soils, fen peats, wooded peats and moss peats. In the prairie region the local soil types formed under the influence of ground water or of periodic excessive humid conditions include meadow soils, saline soils and alkalinized soils. In the aspen grove or the northern black earth region, excessive soil moisture conditions have been responsible for the occurrence of such local soils as saline soils, meadow soils, and swamp podzols.

Where extensive areas of soil with impeded drainage occur in the organized portion of Manitoba, drainage districts have been formed. In these districts open drains and ditches have been installed to improve the drainage. The drainage districts are shown in fig. 9. It should be pointed out that such drainage districts have been organized in the past largely from local

pressure. Drainage schemes, however, should not be undertaken until a soil survey is made of any proposed drainage areas, because drainage may or may not be advisable, depending upon the soil type and the nature of the swamping.

4. Vegetation and Climate

In the foregoing pages the geological surface deposits on which Manitoba soils have been formed, and the physical factors of relief and drainage affecting the soils of the province, have been presented. To understand and appreciate soils, it must be recognized that geological deposits alone are not soils, they are primarily a collection of minerals. Soils are formed only when the mineral material is brought under the influence of living things and of the products of their metabolism and decay. The primary source of soil organic matter is the vegetation. Hence it is important to review the types of vegetation that have influenced the soils of Manitoba. Moreover, as the vegetation is determined by climate, and as climate and vegetation determine the soils, they are inseparable. Because vegetation and climate are so inter-related they will be dealt with together under the above heading.

The native vegetation is extremely important in soil formation because the type of vegetation determines the type of organic material added to soils during their formation under virgin conditions. Vegetation also affects the soil climate, and the soil climate in turn affects the production of vegetation, and controls the rate of its decomposition by soil micro-organisms.

Under a grassland cover the grasses and herbaceous plants grow as perennials and produce organic matter *within the soil.* The herbaceous plants and grasses go into a resting stage in the winter time, but annually some of the roots die and thus organic matter is added to the soil between the soil particles or aggregates. Grassland vegetation may add organic matter both within the soil and as grass mat on the surface, unless the latter is destroyed by fire. This method of deposition of organic matter explains the high organic matter content in the upper portion of, and within the profile of, grassland soils. Such soils with a high organic content are invariably more fertile than soils developed under forest.

On the other hand, it may be noted that the roots of the trees are perennial, and under forest the organic matter added to the soils consists of leaves, etc., which fall on the surface of the ground in the fall of the year. Thus, under timber vegetation, organic matter is added *on the soil* in the form of forest litter, rather than *in the soil* as is the case with grassland soils. Hence the organic matter content in soil profiles under forest is invariably much lower than in grassland soils. Under coniferous woods the forest litter is much thinner than under deciduous trees, and the needles of coniferous trees, which fall on the surface, do not decompose as readily as the leaves of deciduous trees.

The deposition of organic matter on the surface is known as the A_0 layer (A zero). (See fig. 2). The A^0 layer may be present or absent, depending

upon the type of vegetation. It should be noted further that under forest the vegetation is rarely all of the one type, and there may be different levels of plant cover. It is rare in Manitoba to find trees without any other associated vegetation. There may be a crown covering of trees, a shrub cover below the trees, an herbaceous cover below the shrubs, and a cover of mosses below the herbaceous covering. The extent to which these various forms of vegetation exist affects the organic deposition. Under very humid forest conditions mosses will be found growing profusely, and the forest mat will consist of raw acid humus under which acid soils of low fertility are generally developed. Under less humid conditions mosses may be more or less absent and the forest litter may be formed largely from the leaves of the trees and shrubs.

Where the leaf mat is formed chiefly from the leaves of trees and shrubs in the aspen-grove section of Manitoba, the humus produced by the organic deposition is often neutral in reaction and the soils are generally fertile. This is also found to be the case with the humus added to most of the feebly developed grey-wooded soils. The humus in the podzolic or ashy grey forest soils, on the other hand, tends to be of the raw type and generally strongly acid. The forest soils with strongly acid humus are invariably less fertile than the forest soils with neutral to slightly acid humus.

It is apparent therefore that the production and addition of organic matter is determined by vegetation and climate. The decomposition (or humification) of organic matter is also determined by climate, because the latter affects the rate of activity of the soil micro-organisms. Under virgin soil conditions the production and the destruction of organic matter reach an equilibrium with the soil climate, so that the normal soils of any region tend to possess a high or low content of organic matter within the soil profile that is more or less characteristic for each of the respective soil zones.

Under cultivation, the native growths are destroyed by "breaking," plants with different root systems are sown, and the plant products are removed as crops. Moreover, most of the crops (cereals) grown in Manitoba occupy the soil for only part of the open season. Consequently the substitution of cultivated crops for virgin crops upsets the rate and kind of the production and addition of organic matter to soils; and further, the use of fallow, etc., brings about conditions which favor more rapid destruction. Hence under cultivation the organic level of grassland soils falls to lower levels until a new equilibrium between production and destruction of organic matter is reached. This equilibrium level is further reduced by the mechanical removal of finely divided organic matter through the action of wind. (See soil drifting, page 87).

On the other hand, it should be pointed out that when soils which are low in organic matter within the soil are brought under cultivation (as in the case of the ashy grey-topped forest soils from which the leaf mat has been removed), the organic matter produced and added to the soils may be increased by replacing timber with grass vegetation.

(1) Native Vegetation

The forest vegetation of Manitoba has been described in an excellent publication by W. E. D. Halliday.[1] From this work, with a few modifications and additions, a map of the Vegetation Regions in Manitoba has been prepared, which is submitted as fig. 10. A map, on a somewhat larger scale, of the Vegetation Zones in the organized portion of Manitoba, is shown in fig. 11.

The vegetation regions in Manitoba may be divided into:

A. The Grassland Region.
B. The Great Lakes Forest Region.
C. The Boreal Forest Region.
D. The Forest-Tundra Transition.
E. The Tundra Region.

The regions have been subdivided into sections; their approximate boundaries are shown in fig. 10.

A. THE GRASSLAND REGION:

The grassland region occurs in the southwestern and southern portion of the province. This region may be divided into:

(1) The Southwestern Plains.
(2) The Red River Valley Prairie.
(3) The Prairie-Aspen-Grove Section.

(*1*) *The Southwestern Plains:* The native vegetation of the southwestern plains consists of mixed short and tall prairie grasses, with associated herbaceous plants. This section is subject to periodic drought alternated with more favorable moisture conditions. The roots of the native vegetation, when examined in the well drained soil profiles, show a marked tendency to run vertically in the soil, so that the soil splits into narrow columns, the main roots being found more abundantly in the fissures between the vertical columns. As a consequence of periodic droughts, the annual amount of vegetation produced is sometimes low. Hence the total organic matter in this section, although high in the surface soil, tends to be lower in the total soil profile than in the soils of the tall prairie grassland section.

The soils under this type of vegetation in this section are not as dark as in the tall prairie grassland section, their color is dark brown rather than black; their color is the direct result of the kind and method of organic deposition.

(*2*) *The Red River Valley Prairie:* The Red River Valley prairie was developed on the heavy textured soils of the Red River Valley plain. The terrain has a more or less level topography. On the well drained soils the vegetation here was tall

[1] W. E. D. Halliday, "A Forest Classification for Canada"—Forest Series, Bulletin No. 89, Ottawa, 1937.

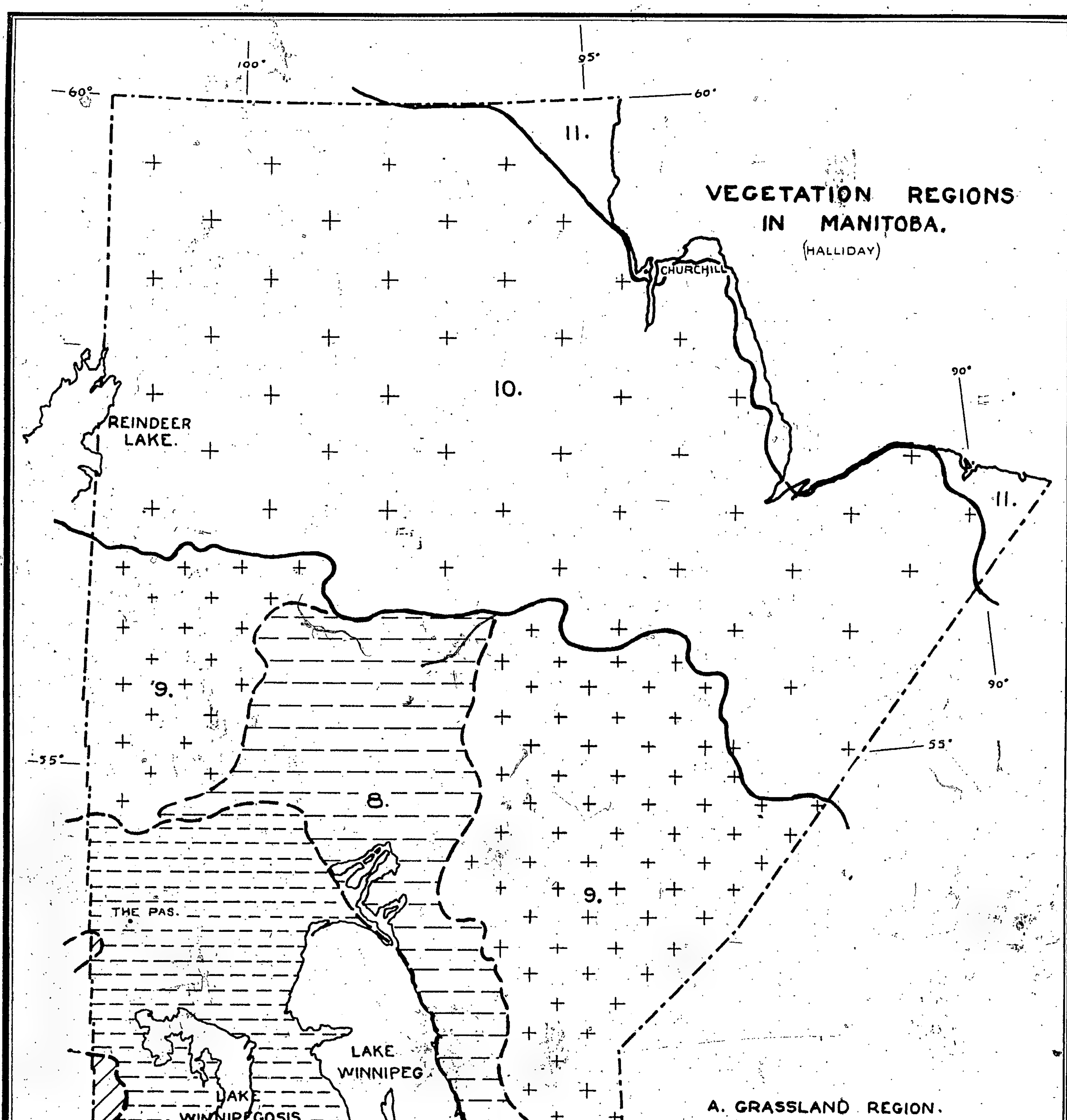


FIGURE 10
The vegetation regions in Manitoba

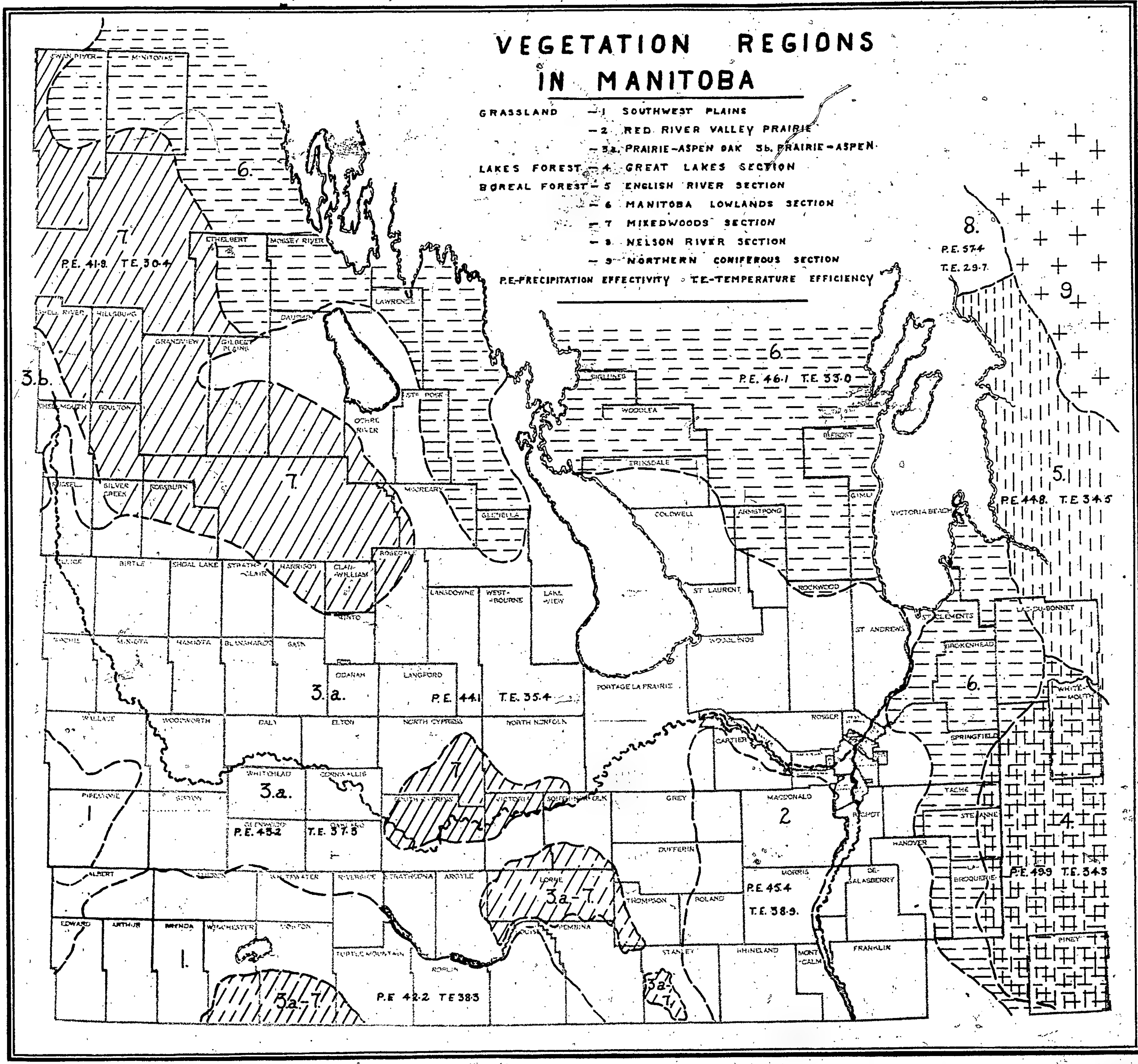


Figure 11

The vegetation regions in the organized territory of Manitoba.

prairie grasses with associated herbs. Because of favorable humidity conditions, the growth was usually abundant, the roots of the plants extended through the soil in all directions, and large amounts of organic matter were produced. Consequently, the soils are dark to almost black in color, and the soil structure is dominantly granular. However, over much of this area the grasses were of the meadow type, due to the spring flooding of a considerable portion of the area by run-off waters from the higher altitudes. In the associated meadow soils the organic matter is high in the upper part of the profile, but it does not extend to as great a depth as in the well drained soils.

(3a) The Prairie-Aspen-Grove Section: The prairie-aspen-grove section originally was probably all more or less prairie, the prevailing type of vegetation being tall prairie grasses, but for many years there has been a woodland invasion taking place, especially in the northern portion, and numerous bluffs of aspen and poplar are common. Aspen groves are found more plentifully around the depressions or locally humid positions, and on the northern and eastern slopes of elevations and stream channels.

In the drier situations, such as on steep ravines or where the soils are shallow over shale rock and over gravel, oak is frequently found along with aspen and poplar woods. In the more humid position, where non-saline meadow-soils formerly occurred, willows and poplar are becoming established. When poplar has been well established, oak may come in as a later stage of woodland invasion.

Large islands of poplar, oak, and other boreal species occur on the Manitoba escarpment and on the tops of the higher altitudes of the Pembina Hills and of the Tiger and Brandon Hills. On the southern boundary of the province, a large island of aspen and oak also occurs above the 1,900-foot contour on the Turtle Mountain. In the sandy portion of the Assiniboine delta there is a considerable area of white spruce, oak and poplar. This, however, is not continuous forest, but occurs as forest growth intermixed with grassland. The species of trees found in this area would suggest that it could be classed vegetatively with the mixed woods section of the boreal belt. However, as it is interpersed with grassland and does not consist of continuous woods, the vegetation is not strictly comparable to the mixed woods section.

The larger part of the prairie-aspen-grove section, however, at the time settlement started, was under grassland, and as the majority of the cultivated and well drained soils were under grasses and have grassland characteristics, this section would be more accurately classed as a grassland section with islands of aspen, etc., rather than as part of the boreal forest region.

(3b) Northwestern Portion of the Prairie-Aspen-Grove Section: In fig. 10 an area in the northwestern portion of the prairie-aspen-grove section is designated as 3_b. In this portion, oak does not generally grow in association with the poplar.

B. THE GREAT-LAKES-FOREST REGION:

This region has only one section in Manitoba (Section No. 4). It extends from the rock outcrop area in the southeastern portion of Manitoba to the high-lime drift deposits east of the Red River Valley. It contains an island of sandy drift and boulders in the Sandilands district. Outside of the rock outcrop in the east, and the light textured area in the Sandilands district, much of this area is poorly drained and swamps are numerous. The vegetation is composed of species of the Great-Lakes-Forest type, namely, white and red pine scattered in the better drained position, associated with white spruce, balsam, fir, elm, basswood, maple and oak. In the less well drained position, black spruce, tamarack, white cedar and white birch are found; and on the granitic outcrops jack pine is common.

C. THE BOREAL FOREST REGION:

The boreal forest region extends across Manitoba from east to west, north of the Lakes-Forest and the Grassland belts. This region has been divided into:

(5) The English River Section.
(6) The Manitoba Lowlands Section.
(7) The Mixed Woods Section.
(8) The Nelson River Section, and
(9) The Northern Coniferous Section.

(5) *The English River Section:* This section includes the English River drainage area. It is relatively low country in which the Pre-Cambrian rocks are for the most part covered by Lake Agassiz sediments. Aspen and balsam poplar occur extensively, sometimes intermixed with white spruce, balsam fir and white birch. Black spruce and tamarack are found in the shallow swamps and jack pine is common in the sandy areas.

(6) *Manitoba Lowlands Section:* The Manitoba lowlands section covers an area where the Palaeozoic lime-stones come near to the surface or are covered with lime-stone drift and modified drift. This area is characterized by high-lime soils and a more or less poorly drained topography. The prevailing forest cover is aspen, black and balsam poplar, mixed with white spruce in the better drained position, and with tamarack and black spruce in the poorly drained situations. Oak often occurs as pure stands on the Lake Agassiz gravel beaches, and jack pine is commonly found where lime-stone rock outcrops. The largest extent of this section occupies the Inter-lake area and the area west of Lake Winnipeg. A strip of high-lime material under similar vegetation, but with somewhat better drainage, extends from Lake Winnipeg to the International Boundary immediately east of the grassland region. The internal effect of the high-lime parent material in this section is dominant over the external climate, hence leaching under forest is retarded and the humus does not become strongly acid.

(7) *The Mixed Woods Section:* The mixed woods section in Manitoba occurs on the Riding, Duck and Porcupine Mountains. The vegetation is made up largely of white spruce, Balm of Gilead and aspen, along with some white elm, ash and Manitoba maple. Jack pine is found on the drier gravelly and sandy situations, and black spruce and tamarack are associated in the low positions with sphagnum bogs.

(8) *The Nelson River Section:* The Nelson River section which extends along the eastern side of Lake Winnipeg is developed on Lake Agassiz deposits. It extends northward from Lake Winnipeg to the Tundra-Forest section. Black spruce forms a large part of the cover, along with white spruce, balsam poplar, Balm of Gilead, white birch, and balsam fir. Tamarack and black spruce occur in the swamps.

(9) *The Northern Coniferous Section:* The northern coniferous section extends to the east and northwest of the Nelson River section. Its soil cover and drainage conditions result in a poor growth of black spruce, mixed with jack pine in the drier positions, and with tamarack on the wetter sites. Aspen, white birch, white and black spruce, and jack pine are also found. Tamarack and black spruce occur in the swamps.

D. The Forest-Tundra Transition:

In the northern transition section the boreal forest grades into the tundra, forming a transitional zone between the forest and the tundra. Because this is a zone of increasingly unfavorable climatic conditions, the tree distribution, and the size of the trees, is reduced. Areas of swamps and tundra are intermixed with stunted forest cover. In the northern portion the trees become dwarfed, finally disappearing as the tundra region is reached.

E. The Tundra:

The tundra, or treeless region of the ever frozen subsoils, extends into Manitoba as a narrow fringe along the Hudson Bay, north of the forest region. A large number of plants make up the Arctic flora, such as sedges and flowering herbaceous species. These have been described by botanists, but the type of organic deposits occurring in the Manitoba tundra has not been studied from the soils standpoint.

(2) The Climate of the Vegetation Sections:

The climate of these different sections varies considerably. Over a large portion the meteorological data is very meagre, and the meteorological figures for temperature and precipitation alone are somewhat difficult to interpret, especially as the meteorological stations are insufficient to cover the province. The native vegetation, however, is a natural evidence of the variations in climate. The native vegetation is nature's record of the climate over long periods of time, whereas meteorological records are man's estimate of climate during the period of observation. For comparison purposes the limited available

figures for precipitation and temperature can be calculated to express the Precipitation-Effectivity and the Temperature-Efficiency by the use of the Thornthwaite formula.[1] The figures thus obtained within each vegetation section, calculated to the mean for each section, indicate forcibly the differences in the climate of the various vegetative areas.

The following Table gives the annual Precipitation-Effectivity Index; the annual Temperature-Efficiency Index; the Temperature-Efficiency Index for the three summer months; the Precipitation-Effectivity for the three summer and the three winter months; and the Temperature-Efficiency Concentration in per cent for the summer months. The climatic provinces for the various vegetation regions and sections in Manitoba are also given symbolic expressions in Table 1.

The annual Precipitation-Effectivity Index values and the Temperature-Efficiency values are given over a map of the vegetation sections in fig. 12. These figures show an increase in Precipitation-Effectivity from the southwest to the northeast, and from west to east. The Temperature-Efficiency Index values show a decrease in Temperature-Efficiency from southwest to the east and north. The index figures for Precipitation-Effectivity and Temperature-Efficiency within each section indicate the climatic differences. These differences are also evidenced in the plant species, and the vigor of growth.

It may be noted, further, that atmospheric climate affects or determines the vegetative regions, but vegetation also affects the soil climate. Under grassland, the native vegetation utilizes the water as it enters the soil and thus tends to keep the soil in the upper part of the profile below its maximum water retention capacity. Moreover, the surface soil is exposed to the drying effects of wind and evaporation. Under timber vegetation the tree roots utilize water at lower depths in the soil profile and from below the soil profile. The tree and shrub canopy over the surface protects the soil from the action of wind and from excessive evaporation, and the leaf mat acts as an absorbent for the precipitation which falls. The leaf mat, and depth at which the root systems utilize water, together result in the upper part of the profile being cooler and more moist than it would be under grassland. This is especially noticeable in the aspen-grove region where trees have invaded the prairie. The invasion of trees causes the soil climate to become more humid and cooler than in the adjacent grassland, with the result that the soil commences to degrade, and the soil type to change slowly.

On the other hand, local soils determine the type of vegetation. The soils in the drier position and with coarser textures, tend to support more drought tolerant (zerophitic) species of plants than the normal vegetation of the district. Soils occupying the lower positions, and especially if under the influence of ground water, support species of plants which are more water

[1] C. W. Thornthwaite, "The Climates of North America." Geological Review, p. 633., Oct., 1931.

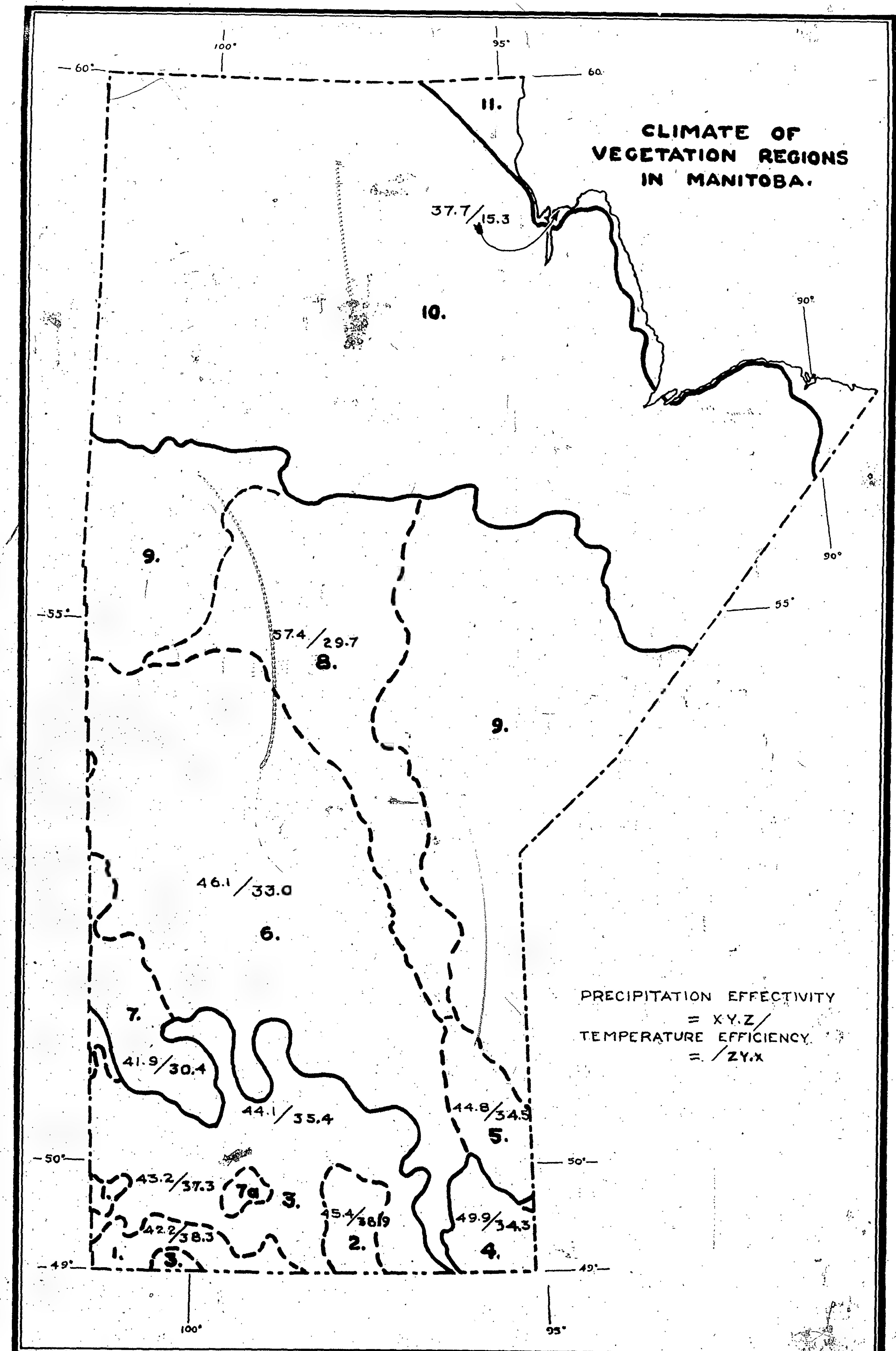


Figure 12.
The climate of the vegetation regions of Manitoba.

TABLE No. I—CLIMATE OF VEGETATION REGIONS IN MANITOBA EXPRESSED BY THORNTHWAITE VALUES

Stations	No. of Stations	P-E[1] Index	T-E[2] Index	T-E Index Three Summer Months	P-E Index		T-E % Summer Conc.	Climatic Provinces
					Summer	Winter		
A. GRASSLAND REGION:								
1. South Western Plains	2	42.2	38.3	23.9	12.7	10.7	62.4	CdC'c
2. Red River Valley Prairie	3	45.4	38.9	24.4	12.3	11.4	65.5	CdC'c
3. Prairie and Aspen Grove:								
(a) North of Assiniboine	10	44.1	35.4	22.6	12.7	10.8	63.9	CdC'c
(b) South of Assiniboine	8	43.2	37.3	23.4	12.6	10.6	62.8	CdC'c
B. GREAT LAKES FOREST REGION:								
4. Great Lakes Forest Section	1	49.9	34.3	22.1	13.8	11.7	64.4	C+rC'c
C. BOREAL FOREST REGION:								
5. English River Section	1	44.8	34.5	22.4	10.8	13.8	64.9	CdC'c
6. Manitoba Lowlands Section	3	46.1	33.0	21.9	12.3	12.8	66.2	CdC'c
7. Mixed Woods Section*	..	41.9	30.4	19.0	15.1	12.2	62.7	CdD'+c
8. Nelson River Section	1	57.4	29.7	20.7	14.2	17.7	69.7	C+rD'+d
9. Northern Coniferous Section	0	....	....	....	....	....	....	....
D. FOREST-TUNDRA:								
10. Forest-Tundra Transition	0	....	....	....	....	....	....	....
E. TUNDRA REGION:								
11. Tundra, Fort Churchill	1	37.7	15.3	13.0	13.7	4.6	84.9	CdE'd

[1]P-E = Precipitation Effectivity.

[2]T-E = Temperature Efficiency.

*Mean of Section, but no data from Manitoba Points.

loving (hydrophitic) than the normal for the district. Moreover, the vegetation of soils with higher than the normal concentration of soluble salts (namely, saline soils) support saline tolerant (or halomorphic) types of vegetation.

5. Age.

Age (or maturity and immaturity) should be noted as a factor in the determination of Manitoba soils. Age refers to the length of time that a given soil has been under the influence of the various soil-forming factors. Geological deposits which have been laid down recently, or which are receiving deposits more or less annually, such as areas of stream over-wash or the recent flood plain deposits found in a number of places in Manitoba at the present time, represent soil material of recent deposition which has not been in position long enough to develop the normal soil characters of the region. That is, the normal soil horizons of the regional soils are absent. The soils may be more or less uniform throughout, and the characteristics of a cross-section through such deposits are those determined by the nature of the material deposited. When the geological material has been in position for a sufficient length of time, the regional soil forming processes will be manifested, and the development of soils characteristic of the region will result. The longer the period of time that a soil has been undisturbed, the better developed the soil profile will be.

Thus immature soils, showing all stages of maturity from recent deposits through varying degrees of maturity, can be observed in Manitoba. Immature soils are more common in the first steppe, east of the escarpment.

In Manitoba, recent deposits occur on the terraces of the Red and Assiniboine Rivers and as stream over-wash in flood plain areas. Such soils may contain considerable amounts of silt and alluvium. The soils found in such locations although immature, are often highly fertile. They have not been degraded or depleted of their initial fertility by leaching or by removal of plant nutrients.

A further point in connection with immature soils in Manitoba may be noted. The soils in the region east of the Manitoba escarpment are not as old as the soils on the boulder till west of the escarpment. With the removal of the ice from the boulder till region of the second steppe, vegetation became established and began to play its part in soil formation. At the same time the waters of Lake Agassiz covered large portions of the first steppe. Glacial Lake Agassiz dried to successive levels over a long period of time. During the interval which elapsed between the earliest stages of Lake Agassiz and its present remainder as Lake Manitoba, Lake Winnipeg and Lake Winnipegosis, vegetation successively kept creeping in over the lake bed, as the waters were removed. As a result, the soils of the first steppe above Lake Winnipeg, Lake Manitoba, and Lake Winnipegosis show varying stages of maturity. The terrain of the first steppe; namely, the land east of the escarpment, has gone through a succession of lake, pond, swamp, meadow and improved drainage

conditions. The effect of this is marked by the relatively recent development of well drained soils over the formerly poorly drained soils, and also by the development of soils with shallow profiles. These dwarf soil profiles, such as are found in the Inter-lake region, are evidences of immaturity. Thus in parts of Manitoba, the influence of age as a determining factor in soil formation is well evidenced.

6. Culture.

The six factors which determine soil type in Manitoba already mentioned, namely, parent material, relief, drainage, vegetation, climate and age, are the factors which primarily determine the soil type in virgin soils. To these six determining factors must be added a seventh (especially in the case of cultivated soils), i.e., the effects of culture or the work of man.

The installation of drainage works, such as drainage ditches, road ditches, etc., has modified or altered the water regime in many of the formerly poorly drained areas, so that modifications of the soil forming processes have been brought about. The effect of forest fires and over-grazing of grasslands by removing the vegetation also has had some influence by exposing the soil surface to more rapid water run-off. However, the greatest effect of culture is brought about when the native vegetation is removed and the land is put under the plow.

Soils may be either improved on the one hand, or severely injured on the other, by cultivation, depending upon the type of culture followed. The degraded forest soils, which are acid in reaction and low in organic matter and fertility, may be improved by the addition of lime and fertilizers and by the growing of grasses and legumes over long periods of time. On the other hand, culture may have very disastrous effects on the fertility of soils if an exploitation policy is practised. The effects of summerfallow and the exclusive growing of grain over more than one-half a century on the fertile soils of the prairies can be seen in inferior or destroyed structure, in the reduction in organic matter, in the effect of soil drifting by wind, and in soil erosion by water. The harmful effects of wind on such soils over a period of years is evidenced by the removal of a considerable portion of the finer soil separates and the finely divided organic materials; in the coarsening of the soil texture; in the reduction in water retention capacity; and, in extreme cases, in the development of blow-outs and moving sand banks. In the heavy textured soils in the open exposed areas and on the knolls, fine materials have been lifted from the surface and carried away by the wind. In the latter case where the soil is too fine to blow into banks it is carried away in the air currents as dust, and soils with truncated (or eroded) profiles are being developed. The continuation of this process will result in complete destruction of the soil through the process of time.

Examples can readily be found in Manitoba of sandy loam soils which have been abandoned because of the exploitation of the soils under the system of exclusive grain growing. However, soils somewhat heavier in texture have

stood up under this system a little better, but considerable areas are now showing evidence of deterioration by wind, and it is only a question of a few more years when they, too, will be ruined if the same system is continued.

Other soils have stood up and will stand up for a considerable length of time under the grain growing system, nevertheless the problem of adopting a land utilization policy, which will use and, at the same time, conserve the soil, is vital for the older settled portions of Manitoba.

Erosion by wind and water combined on cultivated lands is also becoming increasingly important in the areas of rolling and strongly undulating lands in Manitoba. Some lands of strongly undulating and rolling topography in Manitoba, which have been and still are considered as highly fertile soils, are beginning to show the removal of soil from the knolls and higher positions and the accumulation of material by erosion at the foot of the slopes.

The control of soil erosion by wind and water must be systematically attempted in Manitoba or else the destructive effects of an exploitive culture will be the most powerful factor in determining or modifying the condition of the arable soils.

The foregoing pages have been presented to emphasize the fact that the soils of Manitoba as they exist at the present time have been determined by climate, vegetation, parent material, topography or relief, drainage or the presence or absence of ground water, age, and, in the case of cultivated soils, culture or the work of man. It may be stated by way of summary that the chief factor in determining the regional soils is climate. Vegetation is also determined by climate, and climate, vegetation and soils are all interrelated. In each region, however, local soils have been developed because of the influence of parent or geological material, topography, drainage, and age, and, finally, in the case of cultivated soils, such soils have been more or less modified by the effects of culture.

CHAPTER 3.

THE REGIONAL SOILS OF MANITOBA

The soils of Manitoba may be subdivided into zones on the basis of the common characteristics expressed in the normal well drained soils. The regional or normal soils occur on the well drained uplands and the common characteristics expressed in these soils are the basis of the classification of soils into soil zones. The soils in each of the respective zones that differ from the regional or zonal soils may be classed under the heading of "intra-zonal" or "local" soils.

The zones into which the soils of Manitoba have been divided tentatively are given in fig. 13 and fig. 14. The boundaries of these zones south of Township 14 have been established in the field by the Manitoba soil survey. The boundaries of the soil zones north of this line have been tentatively

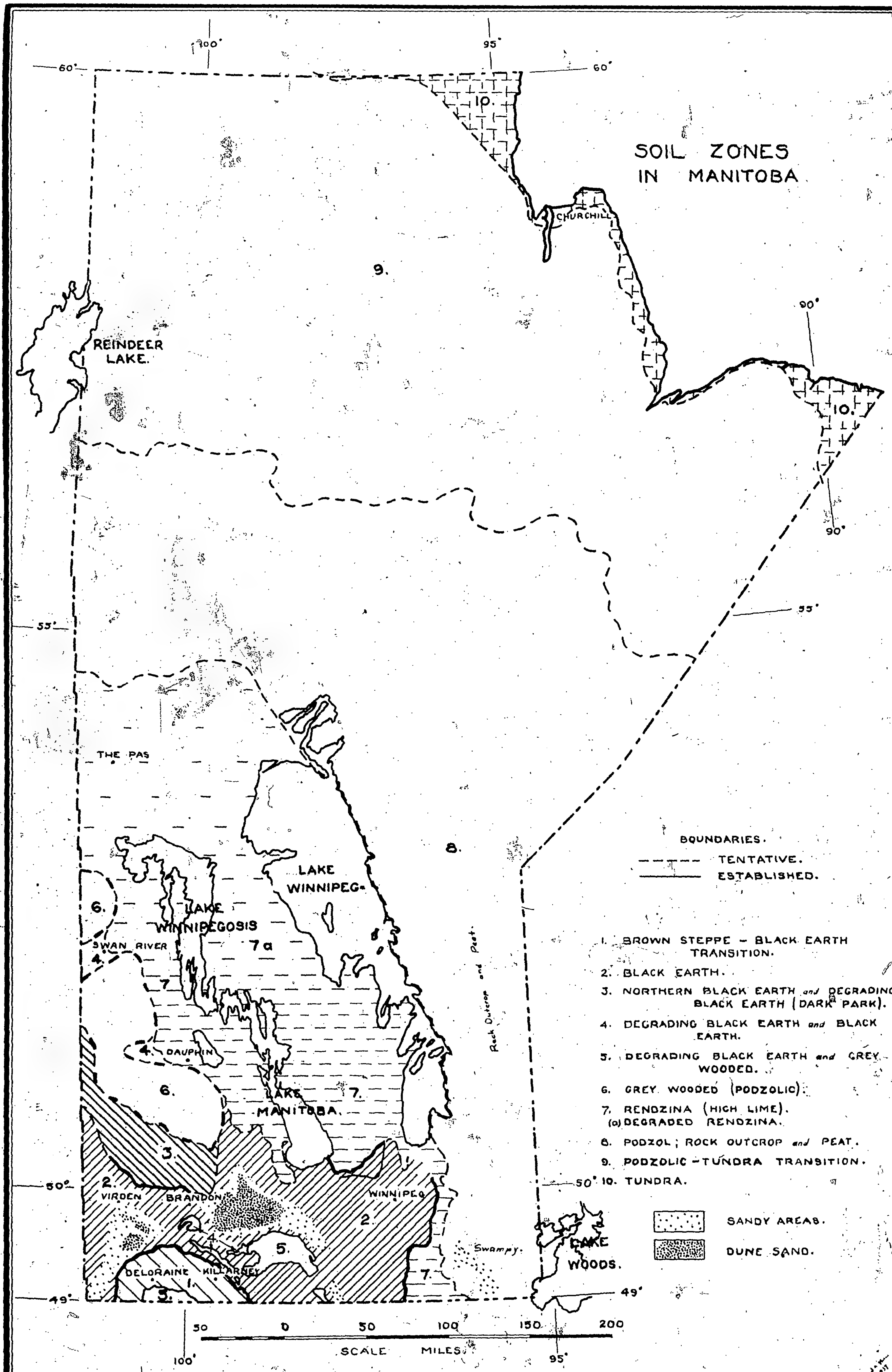


FIGURE 13
The soil zones of Manitoba.

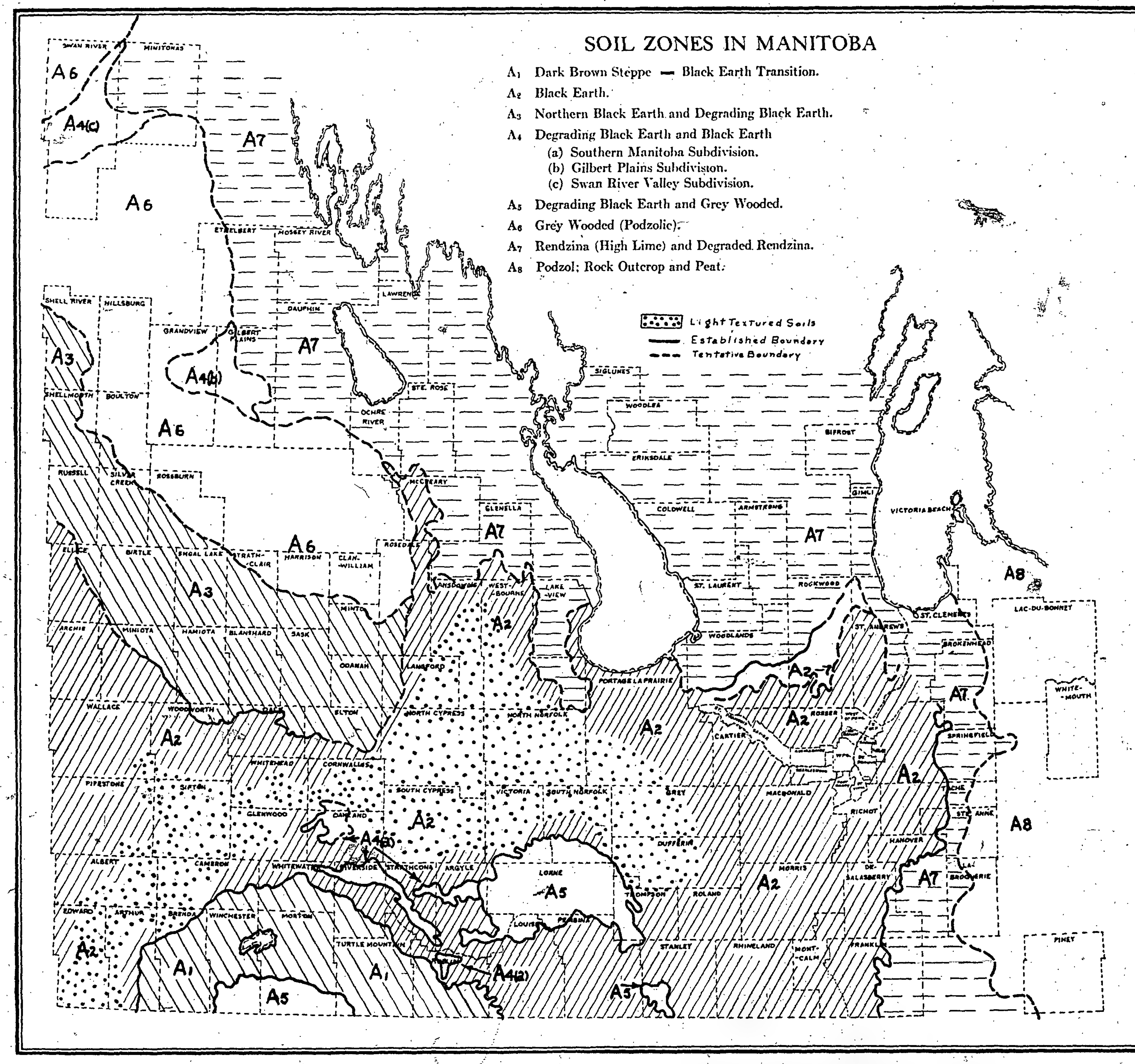


FIGURE 14

The soil zones of the organized territory in Manitoba.

defined from general observation made by travelling over the province and by deductions from all available data. Thus the given boundaries of the soil zones, except those in the south, must be considered as approximate and tentative only. However, they provide a working basis until such time as they are more accurately established as the soil survey work progresses.

As already noted, the basis for establishing the soil zones or belts is the common characteristics of all the soils occupying the normal well drained position in the respective zones. The different parent materials on which the soils are developed within a given zone, and the different local soils that have been developed because of local factors, cannot be shown on a small scale map. Subdivisions of soils into lower categories than the soil zone must be shown on larger scale maps such as are made during the progress of the soil survey.

The different soil zones into which the soils of Manitoba have been divided may be grouped for discussion under three headings, namely, the soil zones of the Grassland Region, the soil zones of the Forested Region, and the soils of the Tundra Region.

1. Soils of the Grassland Region

Three separate soil zones occur in the Grassland Region:

Zone 1. The Dark Brown Steppe-Black Earth Transition.
Zone 2. The Black Earths, and
Zone 3. The Northern Black Earths.

Zone 1: The Dark Brown Steppe-Black Earth Transition Soils:

The well drained soils of the dark brown steppe-black earth transition soil zone occur in southwestern Manitoba. The northern boundary runs approximately from Township 1, Range 12, northwest to Township 6, Range 20, thence southwest to Township 3, Range 26, and from this point straight south to the International Boundary. This includes the Municipalities of Turtle Mountain, Morton, Whitewater, Winchester and Brenda and parts of Roblin, Riverside and Arthur Municipalities.

The southern boundary runs from the southwestern corner of Turtle Mountain Municipality across the southern end of Morton and Winchester Municipalities. South of this line occur the weakly-developed, grey-wooded soils of the Turtle Mountain.

This belt of dark brown steppe-black earth transition soils was formerly an almost treeless plain, under mixed grass and herbaceous plants. From the Turtle Mountain the land falls westward, northward, and eastward across this zone. The native vegetation contains many grass species characteristic of the western steppe flora intermixed with plants which are more typical of the black earth prairies.

The dark brown-black earth transition soils are characterized by a shallow black to dark brown "A" horizon that has a finely granular structure when moist. Below the dark "A" horizon which varies from 4 to 7 inches in depth, occurs a horizon which is dark brown in color, and which has the characteristic narrow columnar structure of the western steppe soils. These brown columns in the well drained positions are of greater thickness than the darker colored "A" horizon. They are usually pointed at the top and become indistinct in the lower portion. The roots of grasses may be seen running vertically down the columns rather than permeating through them. Under dry conditions the columns are firm and will easily lift out of the soil. When moist, they crush in the hand. When the soil dries, the dark colored finely granular surface soil filters between the columns so that they may be colored on the outside with darker material which has filtered in from above. (See fig. 15).

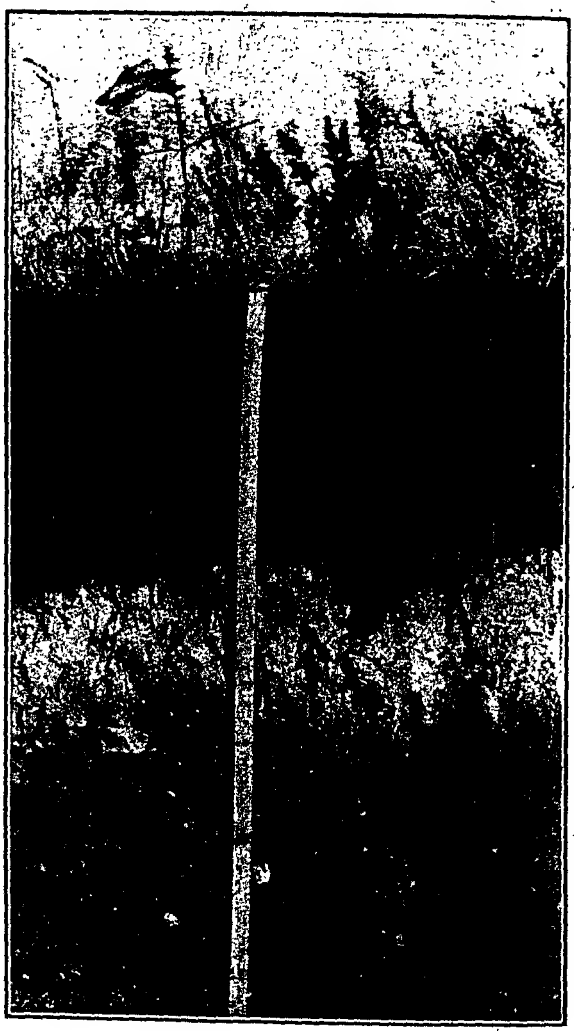


FIGURE 15
Dark brown steppe-black earth transition soil profile, showing characteristic narrow brown columnar structured "B" horizon.

In the lower part of this brown horizon, the brown color fades through a light brown to a buff color. Below the columnar horizon is a friable crumbly horizon speckled with lime carbonate. This horizon grades into the parent material which throughout the greater part of this zone is a creamy-yellow to light buff boulder till.

The lime carbonate layer occurs at a depth of from 12 to 16 inches, although it is deeper on the lower slopes and more shallow on the knolls.

The three outstanding characteristics noted above, namely, the organic accumulation occurring as a black to dark brown finely granular surface horizon;

the brown colored narrow vertical columns in the "B" horizon; and the depth of lime carbonate speckling, indicate the conditions under which the soils were formed.

The height of the carbonate layer in this soil is closer to the surface than in the black earth soils to the north and east of this zone. This implies that drier conditions prevail in this region. The well drained soils of the three grassland soil zones all contain a layer of lime carbonate. This is due to the fact that the moisture which penetrates into the soil is not sufficient to leach the lime out of the soil profile. In the dark brown steppe soils the lime layer occurs higher up in the profile and hence it implies drier soil conditions.

The portion of the profile in which the organic matter accumulates in the dark brown-black earth transition soils indicates periodically moist conditions and periodic drought. During the process of soil formation the soils were moistened in the upper 4 to 6 inches sufficiently to cause the branching of grass roots. This resulted in the development of root systems which permeated in all directions in the upper dark horizon, and also resulted in the addition of organic matter in plentiful quantities. However, instead of the dark colored horizon extending to a considerable distance as in the black earths, it extends in these soils only to a depth of from 4 to 7 inches, which implies that the depth to which these soils have been well moistened is shallow. The brown columnar horizon which occurs between the dark colored surface horizon and the carbonate layer is characterized by roots which are more or less vertical, and these vertical roots generally run down outside of the brown columns. They do not branch or penetrate through the columns to any great extent. This condition indicates that this layer, from approximately 7 to 14 or 16 inches below the surface, tends to be dry rather than moist. During the soil-forming process this part of the soil profile was not usually sufficiently moist to permit of extensive root branching, but during the more moist periods the water penetrated along the outsides of the columns, permitting a downward movement of roots, although the insides of the columns were relatively dry. Thus, the drier conditions induced a vertical type of root system which affected the development of the columnar structure, and the columnar structure affected the development of the roots.

These soils show very forcibly that two outstanding facts must be recognized in the management of the soils of this zone:

(1) These soils are remarkably fertile because there has not been sufficient annual precipitation to cause the leaching of plant nutrients out of the soil, but there is sufficient moisture entering the upper part of the soil profile periodically to induce the building up of a high organic content in the surface soil. This is borne out by agricultural experience, because the soils of this zone produce the highest protein wheat in the province, and if moisture conditions are favorable the yields are relatively high.

(2) The second important fact is that these soils are subject to periodic drought which is often of considerable severity. Even in normal seasons water which penetrates into the soil from the surface is used up by the vegetation, so that it does not percolate in any considerable quantity down below the soil profile. In the wet seasons the soil profile may be moistened throughout, but a dry layer is common below the surface horizon. Hence in the management of these soils the conservation of water and the combating of drought is vital in any cultural management.

Three different topographical phases exist in this zone. Parallel to the Mountain is a rolling phase on which the land slopes in broad gentle rolls from the Mountain to the plain. On the rolling phase, run-off is more of a factor and the best developed zonal soils are found in this phase.

Next, there is an almost level smooth phase, which is found adjacent to the north of the rolling phase, where the land flattens out with no great change in altitude. In the smooth level phase the brown columns in the soil give place to dark brown or black columns, and the brown color may be only feebly expressed in the lower portion. This phase, because of its more level topography, has somewhat more favorable moisture conditions.

Finally, there is an undulating phase, which extends along the northern and eastern portion of the zone. In this phase the surface is more undulating and low knolls or hillocks and small depressions are common. The soils in the normal position on the undulating phase are similar to those of the rolling phase, but the soil on the knolls is usually much more shallow, and the soils in the depressions are often more or less saline.

In the rolling and smooth phases the land is practically all arable, but in the undulating phase there are small areas of non-arable land in the low positions.

In addition to the regional soils, local soils also occur, which include the following:

(a) Small areas of outwash with coarse gravelly subsoils found near Cartwright.

(b) Local saline or alkali soils in the depressed areas.

(c) Shallow black earth soils found intermixed with the dark brown steppe-black earth transition soils, where, because of topographical conditions, or because of the nature of the local parent materials, the soils are somewhat more humid than the regional soils.

In general, however, this zone must be considered as a zone of highly fertile productive soils, very suitable for the production of wheat, but having the problem of periodic drought. The yields will fluctuate from high to low,

but lower average yields may be expected than from the black earth region. The regional soil problems may be enumerated as periodic climatic drought, water conservation, and soil drifting.

Zone 2—The Black Earth Zone:

The black earth soil zone covers the larger portion of the grassland region in Manitoba. It extends from the zone just described, northward to a line running through the Municipalities of Ellice, Miniota, Woodworth, Daly and Elton, and extending around the Assiniboine delta and the Red River Valley, and southward to the International Boundary.

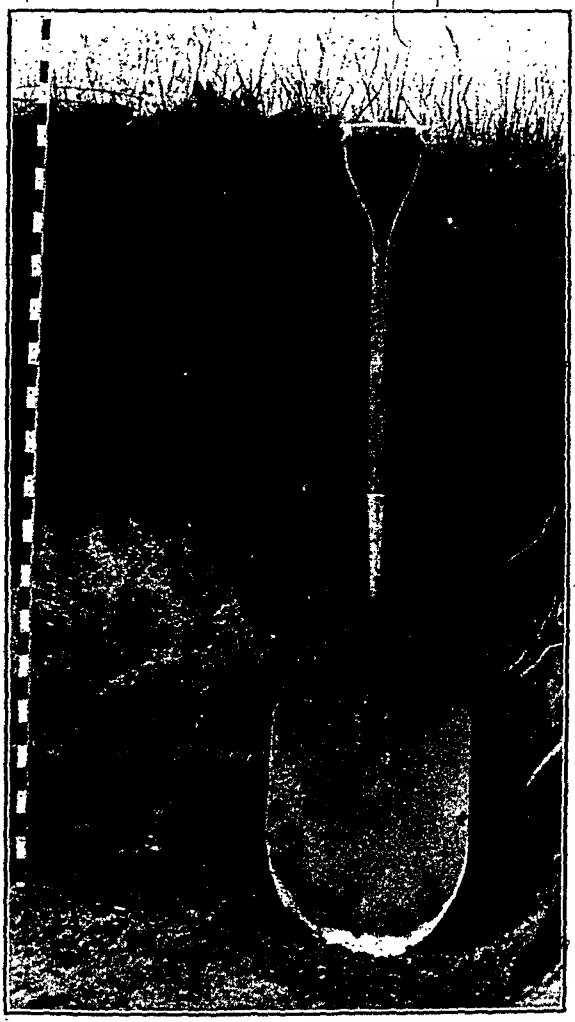


FIGURE 16
Black earth soil profile on lacustrine parent material.

Within this large belt there are a few islands which have been affected by forest vegetation on the higher altitudes, such as the Pembina Hills, etc. The common characteristics of the normal soils through this region are: a moderately deep dark surface soil, granular in structure, and high in organic matter. The black "A" horizon grades through a thin drab colored horizon, underlain by the zone of lime carbonate accumulation. (See figs. 16 and 17 and fig. 1). In the lighter textured soils this horizon tends to be brown rather than drab. The lime carbonate horizon varies in depth, but is usually 16 to 22 or more inches from the surface. The primary structure of the surface of the black earths is granular, but under dry conditions the soil frequently forms aggregates of irregular column-like blocks. These columnar blocks are wider in the eastern portion and become narrower in the western portion. The best developed black earths are found from Holland to Darlingford. In the western part of the zone the soils tend to be more shallow because of the somewhat slightly drier conditions. The

black earth soils of the Red River Valley are somewhat shallower than the average because of their heavier texture.

The greater depth of the black granular surface soil, which fades through a thin drab layer instead of a brown columnar horizon, as in the soils of Zone 1, indicates much more favorable moisture conditions. The taller prairie grasses and the heavier growth of vegetation with more divided root system under the virgin soils of this zone have resulted in the high accumulation of organic matter deep in the soil. The occurrence of lime carbonate at a lower depth than is found in the first zone also implies a deeper water penetration. The medium to heavy textured soils in this zone are undoubtedly the best agricultural soils in Manitoba in respect to fertility and wearing properties. These soils may be expected to give higher average yields than in Zone I, and because of more favorable climate a wider range of crops may be grown.

FIGURE 17
Shallow black earth soil profile on high-lime boulder till.

Owing to the variety of the geological materials on which these soils are formed, a large number of black earth soil varieties are found, the chief of which are:

(1) The black earths developed on heavy lacustrine sediments of the Red River Valley.
(2) The black earths with deeper profiles on light to medium heavy textured lacustrine sediments.
(3) The black earths on the high lime and mixed boulder till of the south, central and western portion.
(4) The black earth soils on low lime shale drift of the Manitou district.

Sand dunes occur as local soils in the Assiniboine delta and in the Souris basin. Between the sand dunes and the medium textured black earths are local areas of sandy soils in which the black earth features are modified by the relative coarseness of the texture.

In addition to the kind of parent material, the topography, position and altitude also vary considerably, so that a large number of local soil associates occur. With a few exceptions, there are no large unbroken areas of the same type of soil, but areas of excellent black earths are interspersed with islands of other soil types, of varying agricultural value. However, the zone as a whole may be subdivided into three soil combinations or sub-zones:

(a) The heavy textured soils of the Lake Agassiz basin, commonly known as the Red River Valley.

(b) The light to medium heavy textured lacustrine soils of the Assiniboine delta and the Souris basin.

(c) The soils of the boulder till area, west of the Pembina escarpment.

(*a*) *The Soils of the Red River Valley:* The soils of the so-called Red River Valley are developed on a heavy textured lacustrine plain. This plain was formerly treeless and covered with tall prairie and wet-land grasses. Owing to the low altitude and flat topography, and to the heavy texture, a considerable portion of this area was originally swamped by run-off waters from adjacent high lands, with the result that about 60 per cent of this area has been under the influence of periodic swamping. Since settlement, the installation of drainage has profoundly modified the soil-forming processes, and much of the area which was formerly meadow soil is now progressing to a better drained condition.

Associated with the regional soils are meadow soils, weakly saline and weakly developed alkalinized soils, and small areas of degrading black earths which are degrading under the influence of woodland invasion.

The chief problems in the soils of the Red River Valley are the control of drainage on the soils with flat topography and the heavy tillage. Dug-outs are the chief source of water for domestic use and for stock. Hence at the present time these soils are used largely for grain growing on mechanized farms, but some mixed farming and dairying is practised. Crop failures are rare, and if water is provided by dug-outs of sufficient capacity, any type of general farming can be followed. The well drained clay black earths of this district are excellent soils for the production of cereals, corn, alfalfa and hay, pasture and garden crops.

(*b*) *The Light to Medium Heavy Textured Lacustrine Area:* The soils of the Assiniboine delta and the Souris basin vary very considerably. The better textured soils, namely, the heavy sandy loams, loams and clay loams, are excellent agricultural soils, generally with smooth topography, and suitable for grain growing and general mixed farming. The most

serious problem with these soils is the control of soil-drifting which is becoming of more importance from year to year. Crop yields average somewhat less than in the Red River Valley, but as crop failures are rare the yields may be expected to average higher than those in Zone 1.

In the lighter textured soils of the lacustrine area, ground water is often present at from 6 to 20 feet, so that there is a certain amount of sub-irrigation from the rise of ground water.

In the centre of the Assiniboine delta from Stockton to Carberry, and in the Souris basin from Lauder to Deleau, dune sands and dunes occupy considerable areas and reduce the amount of land suitable for general agriculture.

The chief problem in the black earth soils on lacustrine material is soil drifting. Drought may be an occasional factor, but it is never of long duration. Evidences of the injury from water erosion are developing in some soil associations (especially west of Brandon).

In the southern portion of the Lake Souris basin from Pipestone and Melita to the International Boundary, there is an area of light to medium textured soils which are not typical black earths, but which have been classed in with them. The air climate in this district is the same as in Zone 1, but the soil climate is modified by the presence of ground water. As the lower part of the soil profiles are under the influence of ground water, the soils more nearly resemble the sandy textured black earths than they do the dark brown steppe-black earth transition soils. Hence they have been classed in with the black earth zone.

The chief problems here are periodic serious drifting conditions in the surface soil. Although the subsoils are invariably moist, soil-drifting is particularly severe.

(c) *The Black Earths Developed on Boulder Till:* Black earths developed on boulder till are found west of the Pembina Hills in the south central portion of Manitoba, and westward to Zone No. 1, south of the Tiger Hills. A narrow strip of the black earths on boulder till also occurs on the west side of the Souris basin on the Manitoba-Saskatchewan boundary.

Four distinct conditions exist:

(1) Excellent black earth soils are found on the boulder till south of the Pembina wooded soils, and associated with these soils are black earths on mixed drift and on shale drift with relatively smooth to broadly undulating topography.

(2) West of the wooded Pembina soils in the Tiger Hills area, the topography is rougher and often sharply undulating or morainic. As a result of this, more run-off from the slopes and less water penetration occurs. In the sharply undulating drift, the soils are often more stony, and considerable areas are occupied by saline depressions and

sloughs. Moreover, in the Tiger Hills area, aspen and oak woods occur on the northern and eastern slopes, whereas the southern and western slopes of the hills were originally grass covered. This difference in topography has resulted in a lesser percentage of available arable land than in the black earth soil developed on drift south of the Pembina woods.

(3) Black earth soils have developed on boulder till west of the Lake Souris basin, but due to undulating topography of low hillocks and shallow depressions this area contains a number of soil types in association with the black earths, and, consequently, the area is very patchy.

(4) In the country south of the Brandon and the Tiger Hills there are large local areas of black earths developed on medium to medium heavy textured lacustrine sediments. These occur as islands in the boulder till area. They are excellent agricultural soils.

If a section is taken across the black earths developed on drift in Manitoba from the Pembina Hills to the Saskatchewan boundary, it will be noted that the soils become more shallow in depth from east to west, and it is also noted that when the soils are dry the black granular horizons tend to form irregular cloddy columns. These cloddy columns are larger in the east and become narrower in the west. On the boulder till along the Saskatchewan border the black earths have weakly developed columnar structure, similar to that of the soils in Zone 1. However, they tend to be black rather than brown, although an occasional strip may be found where the soils cannot be differentiated from those in Zone 1. Moreover, in the black earth region on drift along the Saskatchewan border, the grassland soils are interspersed with aspen groves. The aspen and willow occur as rings of tree vegetation around sloughs in the depressions, in marked contrast to the treeless condition in Zone 1.

The best soils in the black earth zone are found in the Red River Valley, on the smoothly undulating to gently rolling topography west of the Pembina escarpment, and on the medium to medium-heavy textured lacustrine sediments. (See figs. 4 and 14). The black earths on drift, with more sharply undulating rougher topography, are also good soils, but they are often stony, and, as a considerable percentage of the terrain is cut up with depressions and hummocks, there is a considerable area of soils of lesser agricultural value found in association with the good soils.

Zone 3—The Northern Black Earths:

The northern black earth zone extends south and west of the Riding Mountains to the Arrow Hills north of the Assiniboine River. The northern boundary coincides roughly with the 1,900-foot contour, from which the land falls southward and westward towards the Assiniboine. In this area, which lies between the 1,550 and the 1,900-foot contours, grassland and aspen grove

vegetation, developed on boulder till, predominates. The islands of aspen increase in size from south to north, but the country in general has a park-like aspect; similar areas in Saskatchewan and Alberta are designated as the "Park Belt." The well drained soils, however, were developed under grassland. In the southern portion of the belt, aspen occurs as rings of trees around the sloughs in the depressions. Towards the north the trees creep farther up the slopes until in the northern portion the soils on the higher positions only are grassland soils. The northern black earth soils have a deep black very finely granular "A" horizon, and a brown or brownish drab "B" horizon. The black "A" and brown "B" horizons are often of about equal thickness. Towards the south the black horizon tends to be deeper than the brown, but towards the centre the brown tends to be as deep as the black. The typical brown "B" horizon splits into vertical columns which break horizontally, and give a peculiar cubical-fragmental structure. The lime carbonate layer occurs below the brown "B" horizon at a depth of from 20 to 24 inches from the surface. (See fig. 18).

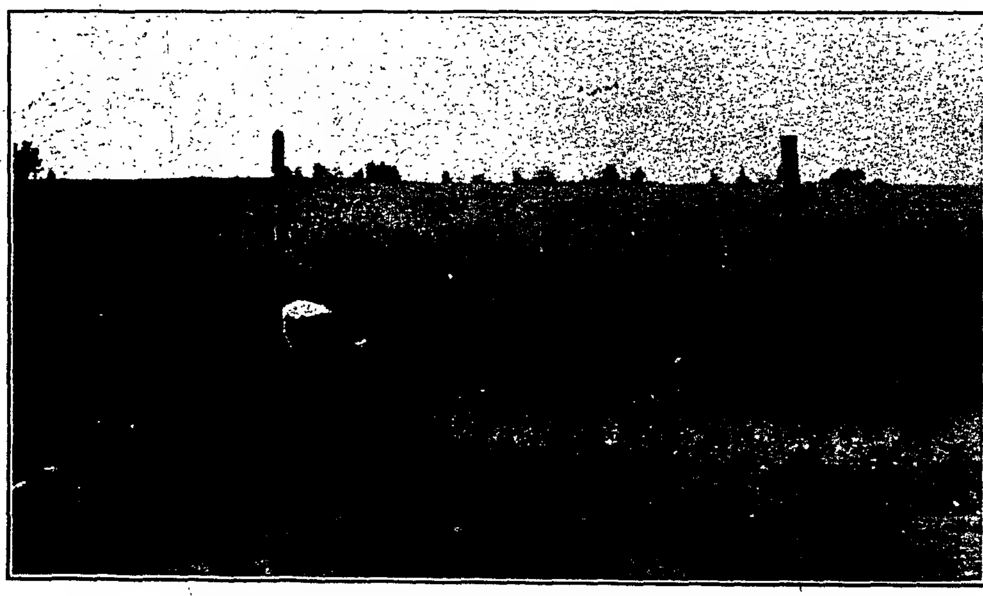


FIGURE 18
Northern black-earth soil profile.

The northern black earth soils are naturally fertile soils, suited to general agriculture, but in Manitoba they have been formed under cooler conditions than the black earths. The cooler condition which prevails in this soil zone in Manitoba is due to the fact that air currents from the west cool as they rise to pass over the Riding Mountains. This cooler condition results in a higher Precipitation-Effectivity, although the actual rain fall is similar to that in the southwestern part of the province. For many years this zone was known as the *oat country*. Excellent crops of oats with heavy weight per bushel were

grown, and the oat acreage in the early years of settlement exceeded the wheat acreage. With the introduction of early maturing varieties of wheat, however, the wheat acreage increased.

Due to the natural high fertility of the northern black earths and to the favorable climate, yields of slightly above the average of the black earth region may occur, but the average protein content of the wheat is lower. The topography is invariably undulating to gently rolling, and on the knolls and in the higher positions a higher quality of wheat is produced, but on the lower slopes, where the soils are deeper, the wheat is often starchy. Thus, there are many fields where wheat crops of mixed protein values are obtained because of the difference in position. This difference of position on the slopes is also reflected in the depth of the soil profile, and in the degree of development of the "B" horizon.

This zone can be considered as excellent for mixed farming. It is particularly suited to the growing of barley and oats, but the percentage of arable land on each farm depends upon the local topography and on the amount of land occupied by depressions and sloughs.

The chief soil problems are soil erosion from the knolls, the numerous basins with impeded drainage, and the tendency to a lower protein content of wheat as compared to Zone 1 and Zone 2.

2. Transitional Zones

Two important transitional zones, which occur as islands, have been mapped out and are shown in fig. 14. These zones are: Zone 4, the Black Earth and Degrading Black Earth Mixed Zone; and Zone 5, the Degrading Black Earth and Grey Wooded Mixed Zone.

It has been pointed out that in Zones 1, 2 and 3 the soils were formerly developed under grassland. In Zones 2 and 3 a woodland invasion of prairie has developed. Islands of woodland are found which have modified the soil they occupy, but these islands are of minor importance in the first three zones. However, some large islands of woodland invasion of prairie occur where the invasion of woods on the grassland soil is of major importance, which justifies the establishing of transitional or mixed soil zones. (See fig. 19).

Zone 4—The Black Earth and Degrading Black Earth Mixed Soil Zone:

The degrading black earths are soils which were developed first as black earths with black earth characteristics, but with the invasion of woods, the soil climate became more humid and the soil-forming processes became modified. Greyish blotches now appear in the dark portion of the soil profile and a somewhat heavier "B" horizon has developed, due to the increase in the percolation of water, and to the different feeding habits of the trees. In the heavier horizon, which develops below the surface horizon in this soil type, the granular structure gives place to a nutty structure and the lime tends to

leach deeper into the soil profile. The term "Degrading Black Earth" does not mean that the soils have become degraded or greatly impoverished, but it is a term used to describe the modifications of the soil-forming processes which are taking place when trees have become established for a sufficient length of time, so that the soils have become modified. Where the degrading black earth soils occur in Manitoba they are generally excellent soils. They have not yet degraded to an impoverished condition because of leaching, but the leaching process is operating. When the leaching process has gone on for a long time the soils take on the characteristics of the grey-wooded soils which are superimposed over the primary soil type.

FIGURE 19
Soils of transition zone showing black soil on the left and degraded soil with grey "A2" horizon at the right of the cross-section.

Areas of degrading black earths, intermixed with black earths, occur in the Tiger and the Brandon Hills. In this area, which may be designated as No. 4_a, the degrading black earths occur on the northern and eastern slopes, although shallow black earths occur on the southern and western slopes.

A sub-zone, which may be designated as No. 4_b, occurs in the Gilbert Plains and Grandview districts in the valley between the Riding and Duck Mountains west of Dauphin. These soils were originally deep black earths, but a general woodland invasion prior to settlement has resulted in the development of degrading black earths. In this sub-zone, woods were dominant, but when the woods were removed the soils were found to be excellent agricultural lands.

A third sub-zone of degrading black earths is found in the Swan River Valley, between the Duck Mountains and the Porcupine Hills. In this broad valley with smooth topography the deep black earths invaded by woodland have given place to a degrading black earth of exceptionally good agricultural value.

The degrading black earths generally coincide with more favorable moisture conditions, with the result that high average yields may be expected if the soil texture is favorable, but such soils generally give remarkable response to the addition of small quantities of phosphate fertilizers.

The degrading black earths are of excellent agricultural value in sub-zone No. 4_b and No. 4_c. In Zone 4_a the presence of shallow black earth in association with degrading black earths, together with the rougher topography, results in soils which are of less agricultural value than in the other two sub-zones. The chief agricultural problem in the soils of this zone is erosion when the tree cover is removed.

Zone 5—The Degrading Black Earths and Grey-Wooded Soils:

A large island in the northern part of the Pembina Hills has been separated out as a mixed zone of degrading black earths and grey-wooded soils. This area occupies the higher altitudes in the black earth zone west of the Pembina Hills and southeast of the Tiger Hills. Trees have been established in this area for a long time. The trees apparently started on the slopes of the escarpment and then moved across and southward over the higher altitudes. A portion of the area has been under woods long enough for the development of grey-wooded soils, but the area also contains a considerable portion which is definitely woodland invasion of prairie. In this zone the deep greyish-black degrading black earths are found associated with the grey-wooded soils, similar to those described in Zone 6.

Zone 5 differs from Zone 4 in that while the degrading black earths are excellent soils, the grey-wooded soils are of lower fertility.

A zone of grey-wooded soils and degrading black earths also occurs on the top of Turtle Mountain. The grey-wooded soils here are more feebly developed than in the typical grey-wooded zone. In the latter area, namely, the Turtle Mountain, the grey-wooded soils are largely found within the Forest Reserve.

3. Soils of the Forested Region

Zone 6—The Grey-Wooded Soils:

The grey-wooded soils in Manitoba occur on the Riding, Duck and Porcupine Mountains. The western boundary between the grey-wooded soils and the northern black earths follows approximately the 1,900-foot contour, although islands of grey-wooded soils extend into the northern black earths zone. In Manitoba, therefore, grey-wooded soils are found as zonal soils

chiefly on the higher altitudes in the northwestern part of the organized territory. They also occur as local soils in the podzol soil zone of eastern Manitoba, and in the aspen grove region.

FIGURE 20
Grey-wooded soil profile on the Riding Mountain.

The original vegetation on the typical grey-wooded soils of the Riding, Duck and Porcupine Mountains was spruce and allied boreal forest trees. Due to forest fires, etc., the vegetation at the present time is dominantly broad leafed trees, especially poplar, etc., which have come in as second growth. Over large portions of the area the second growth appears as well established forest vegetation. The virgin soils are characterized by a leaf mat of forest litter, and a grey platy structured ash-like "A_2" horizon varying in thickness from 4 to 7 inches. Between the leaf mat and the "A_2" horizon, a grey-black crumbly "A_1" horizon may be present where the organic matter from the leaves has been mixed with the upper few inches of soil by organisms. In some cases the grey-black crumbly "A_1" horizon is absent. Below the ash-like "A_2" horizon a well developed nutty-structured "B" horizon occurs. This is the zone of accumulation of clay and humus materials leached from the "A" horizon. Below the tough heavy "B" horizon, which varies in color from reddish-brown to grey-black, there is also a zone of lime carbonate accumulation. This grades into the underlying parent material. (See fig. 2 and fig. 20).

These soils were formed under the influence of more moist conditions in the surface 2 feet of the soil, than in the black earth and northern black earth regions. The soil characteristics indicate that there was sufficient moisture to cause leaching of the upper part of the profile, but not enough moisture to leach the lime completely out of the soil profile. The lime concentration at

from 2½ feet to 3½ feet has enabled the trees to take in their requirement of lime with probably a luxury consumption, and as the leaves were added to the surface the lime became liberated and added to the soil. Although the surface of the grey-wooded soils in Manitoba may be acid to slightly acid, they do not develop the strongly acid conditions of the true podzol soils in Eastern Manitoba and Ontario. The surface soils are generally almost neutral or only slightly acid.

When these soils are cleared and plowed, the soil turns over with a grey ash-like appearance. Where the grey-wooded soil is only feebly developed this soil on plowing is light greyish-brown in color, instead of the ash-grey color which is characteristic of the well developed grey-wooded soils.

In the grey-wooded soils (which were formed under woodland vegetation) there is not so marked a difference in the depth of the profile on the higher position and the slopes as there is in grassland soils, and such as exists on strongly rolling and sharply undulating topography. The soil profiles do not vary to the same extent as they do under grassland cover. The soils of the depressions, however, may be either meadow soils if only partially wet, or they may be peat soils. Tamarack swamps are common in the low positions.

Figure 21

Good setting of alfalfa seed on the grey-wooded soil of the Pembina Hills.

The grey-wooded soils and the Rendzina soils are the best soils in Manitoba for alfalfa seed production.

As a large portion of this grey-wooded zone in Manitoba is under Forest Reserve, only a small portion has been broken up and put under the plow. Grey-wooded soils in Manitoba at the present time are used largely for the production of timber, and though they may be used for agriculture, it must be recognized that the surface soils must be improved in fertility. Although these soils are naturally much lower in fertility in their virgin state, they can be built up into good agricultural soils, providing the

texture is favorable. The surface soils are low in organic matter, and hence low in nitrogen. They are also often low in available phosphorus and there is some indication that some of these soils may show a slight response to potash. In using such soils for agriculture it is necessary to build up the organic matter in the surface soil with barnyard manure, grasses and legumes. The chief soil problems are the building up of fertility and the prevention of soil erosion.

It should be recognized that the grey-wooded soils are more suitable for mixed farming and livestock production and forestry than for the growing of grain. The soil climate in the grey-wooded soils permits of a fair to good average yield if judicious attention is given to the maintenance of fertility. In the production of cereals, barley and oats are more suitable than wheat, because the protein content of wheat tends to be low and the grain to be starchy. Potatoes and root crops are more suitable than corn, but better average yields of grasses and clovers can be obtained than on the prairie soils on account of the more favorable moisture conditions.

FIGURE 22
High-lime or Rendzina soil of the Inter-lake area, developed on modified calcareous drift.

A further point which should be mentioned is that the low nitrogen content of these soils appears to favor the setting of alfalfa seed. (See fig. 21). It is well recognized that the grey-wooded soils will produce larger yields of alfalfa seed than the more highly fertile black earths. On the other hand, grain sown on the grey-wooded soils without fertilizers, tends to give one stalk per seed. Without phosphate the tillering and vegetative growth

is retarded and low average yields are the rule. When such soils are fertilized with manure and reinforced with the necessary fertilizer elements the yields can be markedly increased.

Zone 7 and 7 (a)—High Lime or Rendzina and Degraded Rendzina Soils:

The soils in Zone 7 and Zone 7 (a) found in the West Lake and Inter-lake areas are developed on high-lime parent material. Except for small areas of grassland in the southern portion, and for the areas of peat, the soils were developed under woods. Hence, if it were not for the very high-lime nature of the parent material, these soils would have been developed as grey-wooded soils. However, because the mineral matter is composed largely of material derived from lime-stone and dolomite, the high reserve of lime has prevented the development of the acid soil condition that might have been expected under forest growth. Soils of this type are known as Rendzina soils. (See fig. 22).

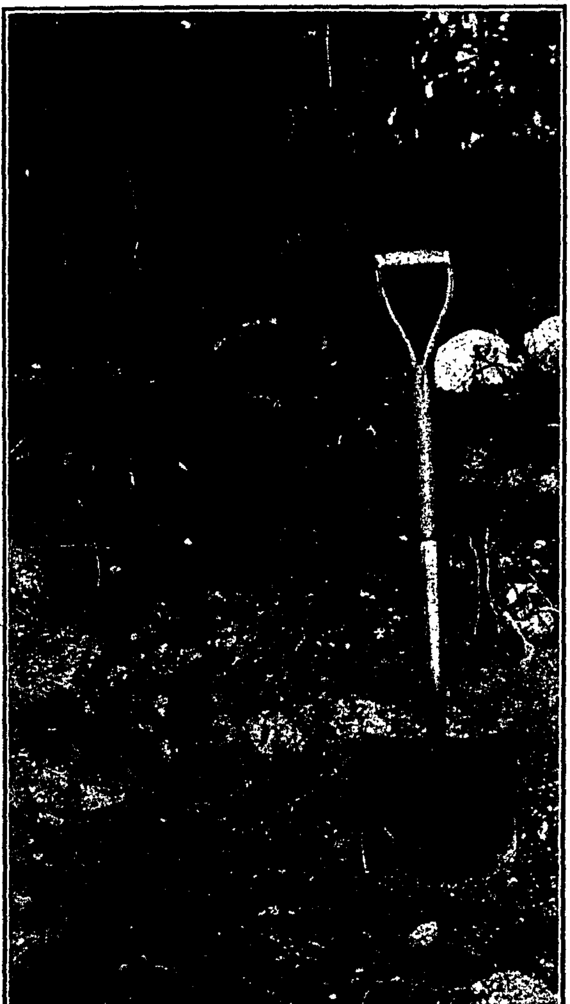


FIGURE 23
Degraded Rendzina in the Fairford District.

The well drained soils in this zone vary from south to north. In the south, whether under grass or woods, the typical soils are characterized by a shallow black "A" horizon, which is finely granular and friable, over a marly carbonate accumulation horizon of a crumbly consistency. The carbonate horizon grades into creamy-yellow buff drift or modified drift.

In the northern portion of this belt, however, the moisture effectivity increases, the temperature efficiency decreases, and the soils show the effects of slight degradation of the surface. The soils which show evidence of slight degradation are characterized by a whitish-grey leached horizon just below the leaf mat. This leached horizon may be only one to two inches in thickness. Below the thin grey horizon is a dark grey-black to greyish-brown nutty-

structured "B" horizon, more compact than the "A" horizon. The thin "A" horizon may be only slightly acid and the "B" horizon generally is neutral to alkaline. Below the "B" horizon is a marly carbonate accumulation horizon underlain by lime-stone drift. (See fig. 23).

The profiles of both the Rendzina and the slightly degraded Rendzina soils are very shallow, the "A" and "B" horizon together often being less than one foot in thickness.

Although the profiles just described are typical of this zone where soils are developed on lime-stone drift, a large number of local soils occur in this region. These local soils have been influenced by the water-sorting of the parent material or by excessively wet conditions.

The West Lake Area: The extreme western edge of the zone is marked by the highest beach of Lake Agassiz which is between 1,300 feet and 1,400 feet above sea level. From this altitude the land falls eastward to the shore of Lake Manitoba and Lake Winnipegosis, the present remains of Lake Agassiz.

Over the area between the upper shore line of Lake Agassiz and the present shore line of Lake Manitoba and Lake Winnipegosis, the glacial lake waters receded and at times remained at a stationary level, so that the whole area has been more or less subject to the action of the waters of this lake. The drift deposits have been modified and sorted by wave action. This water sorting of the high-lime boulder till deposits has been responsible for the varied textural condition of the soils which prevail throughout the West Lake area, and for the sharp changes in soil texture. Numerous lake beaches have been thrown across the country, and stones, cobbles, gravel and shingle are found concentrated in the higher positions due to the separation of the finer materials which were washed into the depressed positions. Where the waves have thrown up well defined beaches, the fine materials such as clay and silt were removed, and the gravel was deposited as more or less rounded stratified gravel beach ridges. On the east or lake side of these gravel ridges, the deposits are invariably sandy and generally stone free. These sandy strips may be from a few rods to one-half mile or more in width, and much of the cultivated land in the West Lake area is found on the east side of these beaches. Across these beaches there is a change in the texture of the soil, the finer textured sands are found in the eastern portion and the soil particles become coarser as the ridges are approached, until the coarse sands grade into gravel under the crest of the beaches. These textural changes across the beaches are shown in fig. 24 (a). The beaches are generally grass covered, whereas the adjacent land is invariably wooded. (See Appendix IV).

Between the beach ridges, the land at first sight appears level or flat. A closer inspection shows the surface to be characterized by a low ridge and swale topography (that is, flat low ridges interspersed with swales or imperfectly drained soils). These low ridges are a characteristic feature of microrelief. See fig. 24 (b). These low ridges are invariably sandy, gravelly or

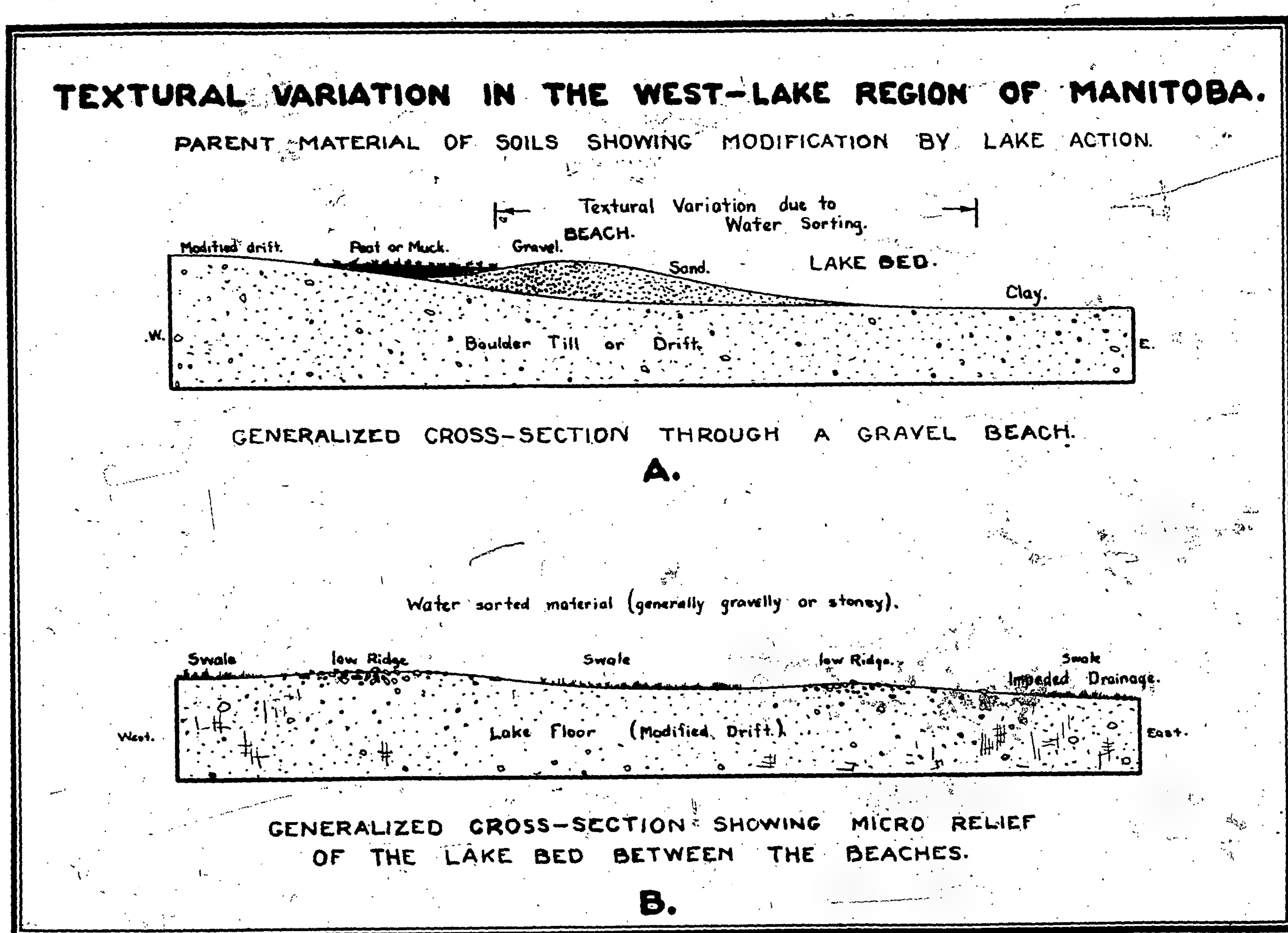


FIGURE 24

Textural variation in the West Lake area due to water sorting:

A. Generalized cross-section through a Lake Agassiz beach.

B. Generalized cross-section of micro-relief and water sorting of the lake bed between the beaches.

shingly at their crest, and in many cases so mixed with stone in the upper 18 inches to two feet, that cultivation is out of the question. In some cases the land between the ridges is too stony or cobbly to permit of cultivation, but in other places the stone may be picked off and the land may be brought into cultivation.

In connection with the surface texture of the soils in the West Lake area, it should be mentioned that although the gravel beaches and the water modified drift of the lake bottom are the most characteristic surface deposits, local areas of high-lime alluvial material have been deposited which are stone free. These local areas of stone-free material may be from sandy loam to clay in texture. They were deposited either by streams which flowed into the lake or deposited as lake sediments in basins which are now dry.

FIGURE 25
Rock outcrop on the central ridge in the Inter-lake area.

Topography and drainage also have played an important role in the development of local soils. Zone 7 occupies a position immediately east of the high lands of the Riding and Duck Mountains which rise approximately 2,400 to 2,500 feet above sea level, or 1,000 to 1,200 feet above the highest point of the area under discussion. The fall eastward down the face of the escarpment is somewhat sharp and in some places from 100 to 200 feet per mile. This results in a periodic heavy run-off of water from the high land eastward through the deeply cut channels and ravines of the escarpment. Where the slope flattens out, these stream channels disappear and as the lake plain is reached, further flow of the water is interrupted by the beaches described above, so that the streams spread out, and swamping of the land on the west side of these interrupting ridges frequently occurs.

In addition to the poor natural drainage resulting from the inflow of water from the escarpment, local swamping of soils has given rise to a further problem which in some cases seriously affects its agricultural value. The surface waters which flow onto the highly calcareous drift become charged with soluble salts. Due to the impeded drainage of the soils, the soluble salts are not removed and the soils are frequently impregnated with alkali. Where the soils are wet the salinized condition is not so acute, but in the periodically wet soils the upward movement of ground water and surface evaporation results in an injurious accumulation of soluble salts. Such areas are under grass without woodland vegetation.

Throughout the area the concentration of lime in the ground water is a general rule and, except in the slightly degraded type, practically all of these soils will effervesce with acid at or near the surface.

Thus, in the West Lake area, in addition to the typical high-lime or Rendzina soils developed on modified boulder till, there are considerable areas of gravelly and coarse textured soils, muck soils, meadow soils with impeded drainage, and smaller areas of salinized or alkaline soils.

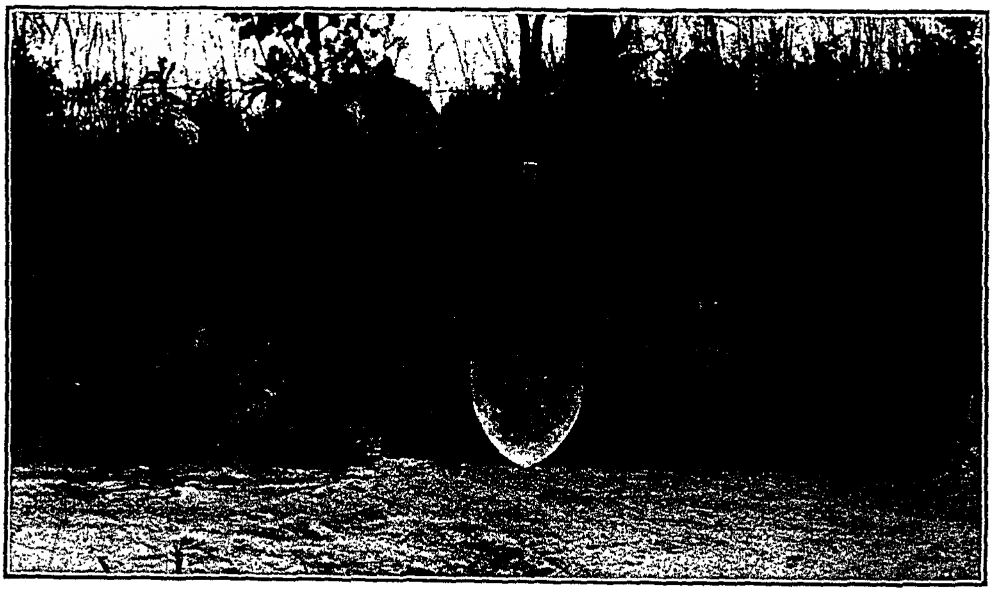


FIGURE 26
Lime-stone rock fifteen inches from the surface in the Inter-lake area.

The Inter-lake Area: In the Inter-lake area the soil parent material also has been under the influence of glacial Lake Agassiz, but, in general, the surface deposits are more shallow than in the West Lake area.

In the centre of the area between Lake Winnipeg (713[1] feet above sea level) and Lake Manitoba (814[2] feet above sea level) the land rises to a broad

[1] Sectional map No. 62, Topographical Surveys of Canada, 1929.
[2] Sectional map No. 72, Topographical Surveys of Canada, 1920.

ridge varying in altitude from 850 to 950 feet above sea level. Under this higher land, Silurian dolomite rock either outcrops or is covered with only a thin deposit of drift. Because of the rock near to the surface on the higher parts of this upper ridge in this area the soils are very shallow and much of the land is of little agricultural value. (See figs. 25 and 26).

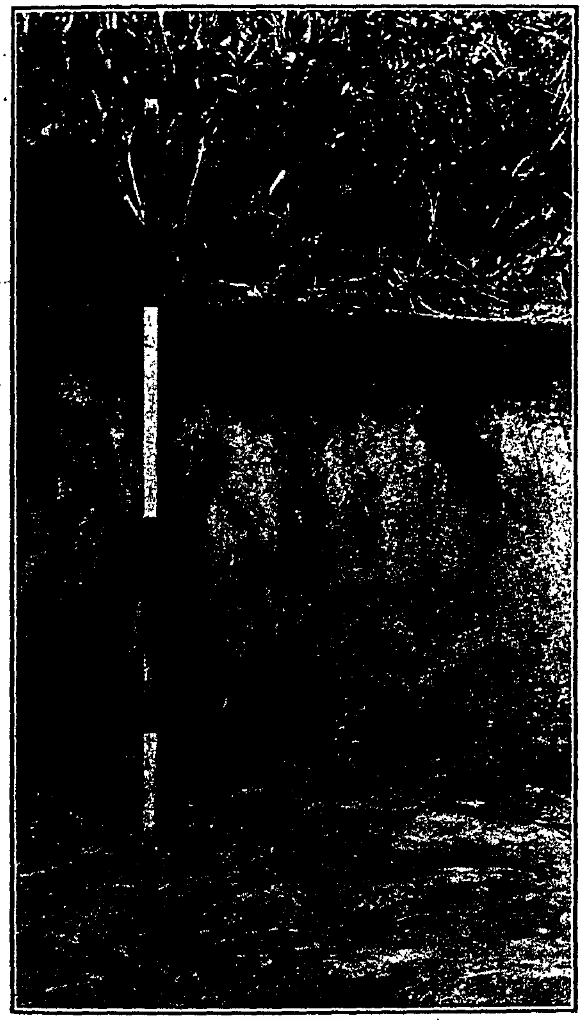


FIGURE 27

High-lime soil developed on calcareous lacustrine deposits in the Arborg district. This soil is especially suited to the growing of alfalfa seed.

From the central rock ridge to the western side of Lake Manitoba soils are found which have been developed on lake-sorted material. From the rock ridge east to Lake Winnipeg the parent material is generally water-worked stony material, but there are also fairly large areas of lake and alluvial clay deposits such as are found in the Matlock, Arborg and Fisher Branch districts. (See fig. 27).

The soils which are stone free or reasonably stone free are good agricultural soils, but owing to the high-lime content they give remarkable response to phosphate fertilizers. Coarse grains, roots and grasses and clovers are the most suitable crops on these high-lime soils, and they are outstanding in their ability to produce alfalfa seed. In the Arborg and Fisher Branch districts yields of from 500 to 600 pounds of seed per acre are common. Alfalfa seed and barley are the best cash crops, but in the main, the better soils of this zone are more suited to the production of livestock and mixed farming, rather than to the production of cash grains. The very stony and the shallow soils should be kept as public domain. (See fig. 28).

Many of the lands in Zone 7 which have been abandoned can be made to grow profitable crops if the surface stones were picked off, and if phosphate fertilizers were applied. This latter statement, of course, applies only if the rock is several feet below the surface and if the soils are sufficiently well drained.

Area East of Red River Valley: A small strip of Rendzina soils occurs south of Lake Winnipeg between the Red River Valley and the swamp and rock area of Eastern Manitoba. This narrow strip of Rendzina soils (high-lime soils), immediately east of the Red River Valley, consists of a more or less stony moraine of high-lime drift which was pushed up in the waters of Lake Agassiz. The soils are shallow and dark in color and they have developed under woodland vegetation of the boreal forest. The high-lime influence of the parent material has prevented these soils from leaching to any appreciable degree. The soils in this area are good general agricultural soils, although in places they may be somewhat stony, and in addition to the production of wheat and other cereal crops, and the general crops of the region, they are especially suited to the production of alfalfa seed. Local areas of soil on Lake Agassiz beach material are interspersed throughout.

FIGURE 28
Stony phase of Rendzina soil in the Inter-lake area. Rock close to surface and surface strewn with boulders.

Peat Soils: Throughout Zone 7, peat soils are found in the depressions. The areas of grassland peat, which are found where the topography is flat or in the depressed positions, are ideal for the production of hay, but the phosphate content of the hay tends to be low, and the yields of hay are often low because of the low availability of phosphate. The application of phosphate fertilizer, however, gives remarkable increases in yields and also increases the phosphate content of the hay. Thus, the logical type of agricultural use of the lands of this zone is the production of hay on the peat lands, for the feeding of livestock, and the production of supplementary feeds on the mineral soils. The production of hay on the grassland peats and the feeding of livestock, with the production

of alfalfa seed and barley as cash crops on the better mineral soils, is the logical method of utilization. The wooded peats are not suitable for agriculture at the present time.

FIGURE 29
Granitic rock outcrop in Eastern Manitoba.

In general, it may be stated that Zone 7 has a small percentage of cultivated land and that this zone contains a large percentage of soils which are marginal or sub-marginal because of one of the following conditions, namely:

(1) The presence of rock outcrop and rock close to the surface.

(2) The occurrence of coarse textured, stony, cobbly or gravelly soils.

(3) The occurrence of large areas of soils with impeded drainage.

On the other hand, much of the area can be developed into productive agricultural soils merely by the removal of the surface stone and by the use of phosphate fertilizer.

Zone 8—Podzols (or Acid Woodland) Soils:

The podzol zone in Manitoba extends in the eastern portion of the province from the Ontario boundary to Lake Winnipeg.

The podzol soils, where they occur, are characterized by a moderately deep whitish-grey ash-like "A" horizon, with a platy structure, and by a brownish or dark colored, nutty-structured, heavier textured "B" horizon. Except where drainage is impeded, the rainfall is sufficient to remove the lime from the soil profile and these soils are acid in reaction.

The podzols (or ashy-grey topped wooded soils) have developed under more humid climatic conditions than the grey-wooded soils. The former soils have a more acid surface and lack the lime carbonate accumulation horizon of the latter soil type.

This zone coincides with the Laurentian Shield. Over the larger part of this zone in Manitoba, glaciation was so severe that the loose surface material was entirely removed, and, at the present time, large bosses of granite rocks outcrop. The predominance of rock outcrop, rather than soil development, is the outstanding characteristic of this area. (See fig. 29). Jack pine and other trees are found growing out of the cracks and fissures of these rock outcrops.

Where glacial material and lacustrine sediments occur over the rock, the normal podzol soils of the region are developed. Tamarack swamps and moss peats which are acid in reaction are common. Numerous streams traverse this rock region, and, frequently, adjacent to these streams, alluvial flood plains occur. The soils ~~which have developed on the alluvial flood~~ plains are the best soils of the region. On the river flood plains and terraces grey-wooded soils, rather than podzols, have developed as local or intrazonal soils. (See fig. 30).

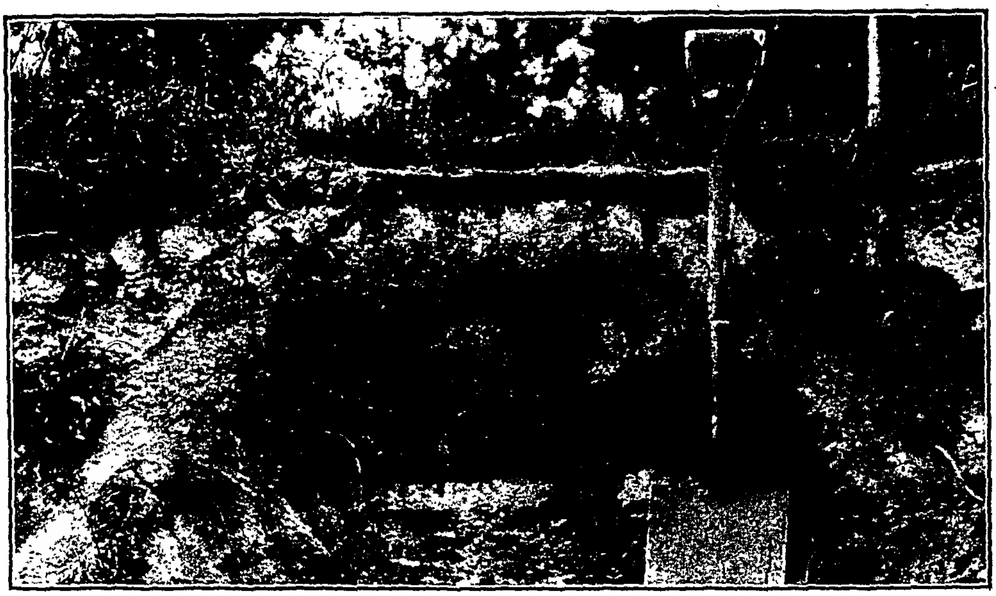


FIGURE 30
Podzolic soil developed on alluvial flood plain in Eastern Manitoba.

The chief problem with the acid podzol soils is the building up of fertility. The local grey-wooded soils, on the other hand, make excellent mixed farming soils. Due to the prevalence of rock outcrop and peat, this area will never sustain any extensive areas of agriculture and the logical utilization of the major portion of this zone is the production of forest and wild life as public domain. The innumerable lakes, streams and rapids are ideal for summer resorts.

4. Soils of the Tundra Region

Zone 9—Forest-Tundra-Transition, and Zone 10—Tundra:

These zones have not been studied from a soils standpoint.

From the podzol region (Zone 8), the land falls northward to Hudson Bay. Trees become smaller and smaller until the tundra is reached. Much of the forest-tundra-transition is under impeded drainage and islands of tundra enter southward into this transition belt.

The tundra is characterized by an ever-frozen subsoil. Both the tundra and the forest-tundra-transition zones are non-agricultural because of the climate.

Summary of the Characteristics of the Zonal Soils:

The general characteristics of the major soil zones of Manitoba are summarized in Table II. on pages 66 and 67.

CHAPTER 4.

LOCAL OR INTRA-ZONAL SOILS

It has been pointed out that the well drained soils in the normal position have morphological characteristics that are common to the regional soils, but within each soil zone there are different varieties of regional soils due to differences in parent material, and there are also differences in soil type due to differences in topographical position or drainage. The regional soils of one type may be found as islands extending into an adjacent soil type. For example, small islands of grey-wooded soils may extend into the black earth zone, and islands of northern black earths may be found in the grey-wooded soil zone, etc. In each zone, soils with dwarf or shallow profiles that are not as well developed, occur on the knolls and on the upper slope positions. In each zone different varieties of the regional soil occur because of the difference in geological parent material, and while the common regional characteristics will be present, there will be some modification in structural condition, depth, color or other difference.

Light, sandy soils and soils composed largely of skeleton material may show only feeble development of the regional soil characteristics. The coarse-textured parent material has a less water retention capacity than the medium to medium-heavy textures, and hence they are more arid than the regional soils and this influences markedly the degree of expression of the soil-forming processes.

In addition to the different varietal expressions of the regional soil types there are a number of local soil types found in association with the regional soils. These different local types often result from impeded or arrested drain-

TABLE No. II

THE MAJOR SOIL ZONES IN MANITOBA

Zonal Soil Type	Profile Characteristics of Typical Zonal Soils	Associated Intra-Zonal Soils	Regional Soil Process	Native Vegetation	Climate	Natural Fertility	Dominant Agricultural Use Indicated	Regional Soil Problems
(1) Dark Brown Steppe-Black Earth Transition.	"A" Hor. Black to dark brown in color. Granular micro-structure, often arranged in cloddy columnar aggregates. Consistency: friable. Reaction: alkaline to neutral. "B" Hor. Reddish brown to grey-brown in color, with various degrees of black staining, fades to light brown below. Structure, narrow columns, pointed on top. Consistency: columns firm when dry, friable when wet. Reaction: alkaline. Calcium Carbonate Horizon. Flecked, effervesces at the base of "B" horizon, or approximately 14".	Black earths where topography is level. Solonchak, Carbonate } Meadow soils. Solonchak, Solonetz and Solods.	Calcification.	Mixed grassland.	P-E 41.7 T-E 38.2	Good.	Grain production.	Periodic climatic drought (seasonal or annual). Water conservation acute. Soil drifting. Soil drought. Water run-off on the rolling phases with periodic erosion.
(2) Black Earth.	"A" Hor. Black in color. Granular micro-structure, arranged in irregular prismatic columns, narrower in diameter in western portion. Consistency: friable. Reaction: alkaline. Deepest: Holland to Darlingford, and particularly on lacustrine sediments. Shallower westward and on heavy clay (Red River Valley). "A-B" Hor. Drab in color, dark stained, tends to brownish in western portion of zone. Structure: coarsely columnar blocks often with angular rather hard fragments. Consistency: more compact than dark "A." Calcium Carbonate Horizon. Varies in depth from 22" to 16".	Soils developed on weathered shale are weakly columnar to cloddy with powder micro-structure in the "A" horizon and grey-black to black in color. The "B" horizon is grey drab to very dark drab in color, with structure very similar to that in the "A" horizon, although slightly more compact. Carbonated, Solonchak } Meadow soils. Solonchak, Solonetz and Solods.	Calcification.	Tall prairie grass.	P-E 44.6 T-E 37.4	Good to very good, but fair where parent material is high in lime.	Grain production and mixed farming.	Soil drought. Occasional climatic drought (seasonal or annual). General conservation of water. Soil drifting. Soil erosion in some soil associations. Example (Kenton-Carroll). Drainage on heavy clays, with flat topography. Example, Red River Valley.
(3) Northern Black Earth (Dark Park. Sask., Alta.) and Degrading Black Earth.	"A" Hor. Black in color. Structure: finely granular. assumes column-like blocky structure when dry. Consistency: mellow and friable when moist. Reaction: slightly alkaline. "B" Hor. Brown to drab in color. Structure: narrow column-like aggregates which split horizontally, giving characteristic cube-like structure. Consistency: friable. Reaction: alkaline. Calcium Carbonate Horizon. Marly and carbonate-flecked.	Degrading black earths in phytomorphic-hydromorphic position, and on the slopes in the northern portion. See description for Degrading Black Earth (5). Black Earth (2). Solonchak, Carbonate } Meadow soils. Swamp podzols, Solonchak and Solonetz.	Calcification in normal soils, with super-imposition of podzolization under wood-land invasion.	Tall prairie grassland with islands of aspen.	P-E 41.7 T-E 33.3	Good.	Mixed farming and grain growing. Excellent oat and barley region.	Erosion of knolls. Numerous basins with impeded drainage. Lower protein in wheat.
(4) Black Earth, Degrading Black Earth Intermixed.	Black earth and degrading black earths, with weakly developed wooded soils where woods are well established. Black Earth—See (2). Degrading Black Earth—See (5)	Solonchak, Carbonate } Meadow soils. Swamp podzols, Solonchak, Solonetz and Solods.	Calcification and podzolization. Podzolization super-imposed over former calcification.	Invasion of aspen and poplar, etc., on former grassland on northern and eastern slopes in the Black Earth Belt.		Generally good, although somewhat reduced fertility at the surface in some local areas under well established woods. Good except where the lime content of the soil is very high.	Grain growing and mixed farming.	Erosion when tree cover is removed.

TABLE No. II—*Continued*

Zonal Soil Type	Horizon	Profile Characteristics of Typical Zonal Soils	Associated Intra-Zonal Soils	Regional Soil Process	Native Vegetation	Climate	Natural Fertility	Dominant Agricultural Use Indicated	Regional Soil Problems
(5) Degrading Black Earth and Grey Wooded.	(4)	Degrading black earth. Profile same as black earth except that grey blotches due to silica grains appear irregularly in the "A" horizon and the "B" horizon shows a weakly nutty structure (with grey speckling). A leached A_2 horizon and a "B" horizon with weak but characteristic grey wooded structure are developing, although the columnar structure of the prairie soil is still discernible.	Carbonate meadow soils. Swamp podzol. Shallow muck and peat.	Podzolization super-imposed over calcification.	Woodland invasion.	P-E 43.9 T-E 36.2	Good in the degrading black earth soils, slightly lower surface fertility in associated grey wooded soils.	Grain growing and mixed farming.	Erosion when tree cover is removed.
	"A" Hor.	Grey drab to grey-black mottled color. Structure: weakly cloddy and granular, Sometimes platy. Consistency: friable. Reaction: neutral to slightly acid.							
	"A-B" Hor.	Grey-black to grey-brownish drab color. Structure: granular to nutty. Sometimes columnar. Consistency, more compact than "A," not as compact as "B" horizon. Reaction: alkaline.							
	"B" Hor.	Brown to drab in color. Structure: nut, from pea to walnut size. Feebly columnar. Consistency: tough and compact. Reaction: alkaline.							
(6) Grey Wooded.	A_0 Hor.	Leaf mat.	Carbonated meadow soils. Shallow peat and muck soils. Swamp podzol.	Podzolization.	Boreal Forest.	P-E 41.9 T-E 30.4	Generally good, although the fertility is slightly lower in the surface horizon of these soils.	Mixed farming.	Low in organic matter in surface. Erosion control where woods are removed. Low protein in wheat.
	A_2 Hor.	Grey in color. Structure: platy. Consistency: ash-like. Reaction: acid, more or less.							
	"B" Hor.	Brown, dark grey to black variable. Structure: B_1, finely nutty; B_2, coarsely nutty. Consistency: tough and more or less compact, heavier than "A" horizon. Reaction: acid above to neutral or slightly alkaline below. Calcium carbonate accumulation below the "B." Effervesces at B_2 to C_1.							
(7) Rendzina.	"A" Hor.	Thin and decidedly black in color. Very granular and friable, underlain by a marly carbonate accumulation of crumbly consistency, over high lime parent material (lime-stone drift). Reaction: alkaline.	Carbonated meadow soils. Swamp podzol. Shallow peat and muck. Solonchak.	Calcification. High lime parent material dominant over climate.	Boreal forest and grassland intermixed.		Frequently low. High calcium content interferes with the nutrition of plants.	Dairying, livestock and mixed farming where texture is favorable and rock is not too close to the surface. Excellent for alfalfa seed production.	Fertility—low phosphate availability. Drainage. Coarse textured, stony, cobbly, gravelly soils. Shallow root depth. Drainage where topography is flat. Management of peat.
(7a) Degraded Rendzina.		Occurs in northern portion of Soil Zone No. 7.	Carbonated meadow soils. Swamp podzol. Shallow muck and peat. Deep high lime muck and peat.	Slight podzolization over calcification.	Boreal forest.	P-E 43.8 T-E 34.5	As (7), but less acute excess lime.	As (7).	As (7).
	A_0 Hor.	Leaf mat.							
	A_2 Hor.	Whitish grey in color, but thin in depth. Consistency: ash-like. Reaction: slightly acid to neutral.							
	"B" Hor.	Dark in color (grey-black to greyish-brown). Structure: nutty, more compact than in "A." Reaction: neutral to alkaline.							
	Carbonate accumulation.	Marly and crumbly over high lime parent material. (Lime-stone drift).							
(8) Podzol, Rock Outcrop and Peat.		Strongly glaciated Pre-Cambrian rocks, with peat in the low positions. Soils of river flood plains as (6). Soils of well-drained upland are podzols, i.e., more strongly leached than the grey wooded, and without lime carbonate accumulation.	Deep acid peat. Swamp podzols.	Podzolization and gleization.	Boreal forest.	P-E 57.4-44.8 (S) T-E 29.7-34.5 (S)	Low, except in river flood plains.	Mixed farming in small scattered communities. Hay production. Dominant use: timber and fur.	Fertility. N and K_2O, and in some cases P_2O_5. Drainage. Water erosion control. Management of peat. Acid soils in north.
(9) Podzolic-Tundra Transition.		Not yet studied.	Tundra and peat.	Podzolization and gleization.	Boreal forest-tundra transition.	No data.		Non-agricultural.	Low temperatures.
(10) Tundra.		Not yet studied.			Arctic Tundra.	P-E 37.7 T-E 15.3		Non-agricultural.	Low temperatures. Ever frozen subsoil.

age, or because the soils are developed in locally wet or low topographical positions. The most important of the intra-zonal soils found in Manitoba may be listed as:

(1) Peats.
(2) Swamp Podzols.
(3) Meadow Soils.
(4) Alkali Soils.

1. Peats

Peat soils occur in Manitoba under locally humid conditions. They occur chiefly in the wooded regions. They may occur as small islands or they may extend over a considerable area. The peats may be classified as:

(a) Fen or grassland peats.
(b) Wooded peats.
(c) Moss peats.
(d) Mixed peats.

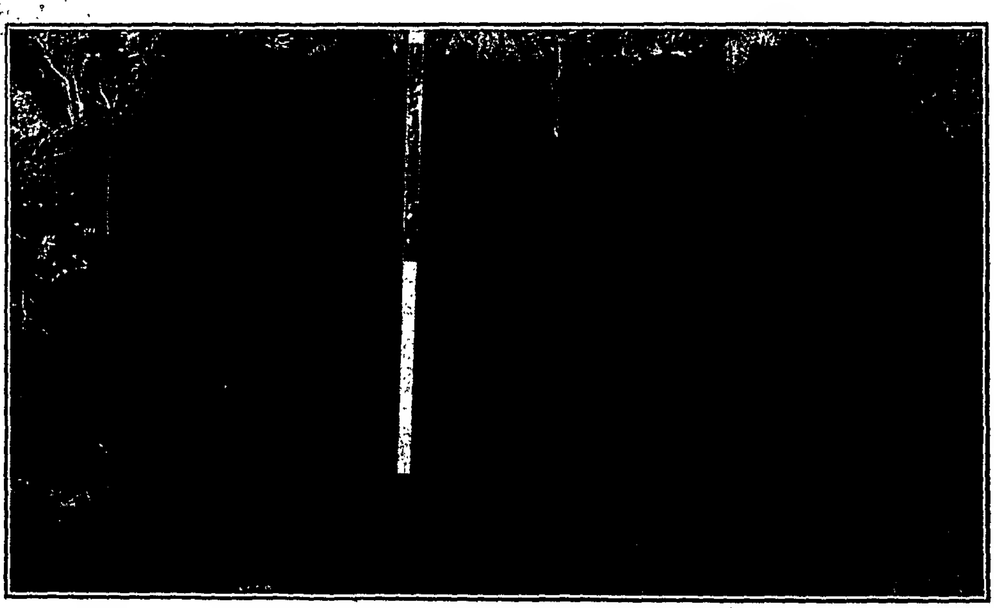


FIGURE 31
Fen or grassland peat in the Inter-lake area.

(*a*) *Fen Peats or Grassland Peats:* Grassland peats occur quite extensively in the Inter-lake and West Lake area in association with Rendzina soils. They consist of organic deposits which have converted ponds and water surfaces into land surfaces by the deposition of organic matter in water. All stages in the development of the fen peats may be observed from the stagnant water with pond lilies and aquatic plants, followed by reed swamps, cat

tails, sedges, and grass cover. As these plants die their remains are deposited in the water (and because of the lack of air and the excess of water, the processes of decomposition of the organic matter that proceed in the well drained mineral soils cannot take place), and the organic matter accumulates as peat. The organic material of the fen peats may be either felty or fibrous, or it may show all stages of disintegration to a brown mold which is sometimes known as muck. As the fen peats are usually formed in the low position, they receive drainage water and run-off water from the adjacent lands so that different amounts of mineral sediments may be washed in and mixed with the organic material.

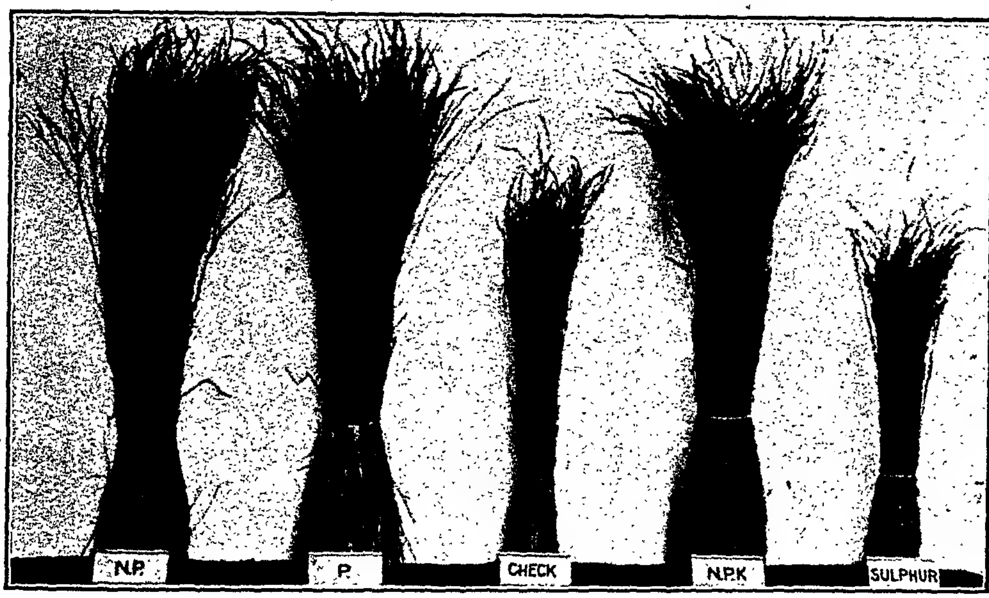


FIGURE 31a
Square yard samples of hay, Arborg district, showing the response obtained from phosphate fertilizer.

In the Rendzina high-lime soil zone (Inter-lake and West Lake area), the waters in the peats are strongly charged with lime, so that the fen peats in this zone are invariably high-lime peats. (See fig. 31 and fig. 31a).

These grassland peats are used extensively for the production of hay. The native hays, however, generally contain a large percentage of sedges and the hay is generally low in phosphate. These peats respond remarkably to phosphate; the application of phosphate not only increases the yield of hay to a marked degree, but its application also results in an increase in the phosphate content of the ash. Hay fed from the fen peats which have not been treated with phosphate tends to cause mineral deficiency in cattle unless they are fed sufficient grain or a mineral supplement.

Fen peats are not suitable for general agriculture, but they are exceedingly useful lands for the production of crops where leaf and stem is required. Cereals on peat tend to produce heavy yields of straw with a low yield of grain. Fen peats which are well decomposed are excellent for the production of potatoes, roots, lettuce, onions, celery, etc., but on account of the lack of markets the logical use for these lands is the production of hay.

To secure the best results from these peat lands the fundamental principles of management that should be followed are:

(1) Drainage with control checks in the drainage ditches, so that the water may be kept at any desired height, and the land thus prevented from being either too wet or too dry.

(2) The application of the necessary fertilizer, which in the case of the fen peats in the Inter-lake area is phosphate.

(3) The maintenance of a compact condition in the peat by rolling with a heavy roller.

(4) The selection of grass hay crops which will stand the cold, wet conditions.

Crops grown on extensive and deep peat areas are liable to frost injury, and legumes and some other plants will kill out because of the cold, wet subsoil conditions.

Fen peat lands are useful in conjunction with mineral soils for the raising of livestock.

(*b*) *Wooded Peats:* Wooded peats, which in the wooded regions of Manitoba are generally tamarack and black spruce swamps, are not suited for agriculture. They may be more or less acid, and the dominance of woody material results in the physical condition of the peat that precludes their use for agriculture. They are best utilized for the production of timber.

(*c*) *Moss Peats:* Moss peats may occur both in the low positions and on the higher land. They are formed (under humid and wet conditions) from sphagnum moss, leather-leaf and similar plants. These plants may form the dominant vegetation, but many other wet land species are found in association. Moss peats are not worth reclaiming at the present time. They occur chiefly in the podzol region in Eastern and Northern Manitoba.

(*d*) *Mixed Peats:* Mixed peats are peats which have been formed under varying conditions. Fen peats may be intermixed with wooded and moss peats. Changes in drainage in times gone by may have been responsible for the change in vegetation, so that felty, woody and fibrous peats may be found superimposed one upon the other. The reaction and the physical condition of the surface layer will determine whether such soils are worth attempting to reclaim.

Farther north in the wooded area, shallow deposits of moss may occur mixed with the forest litter under timber growth that is not necessarily in a low position. This results in the development of an acid humus forest layer, so that the underlying mineral soil becomes strongly acid. Such soils, however, are classed in with the wooded soils under raw humus, rather than with the peat soils.

Many thousands of acres of peat lands occur in the wooded region of Manitoba, where the topography is flat or where drainage is impeded.

FIGURE 32
Profile of a swamp podzol or acid meadow soil.

2. Swamp Podzols

Swamp podzols (or acid meadow soils) are found in the depressions in the northern black earth zone, in the northern portion of the black earth zone, and in the wooded area where it is not wet enough for the formation of peat. These soils are found in the depressions where excessive amounts of run-off water percolate slowly through the soil. They generally have a layer of muck at the surface with a black mucky "A" horizon. Under this dark surface horizon is a whitish-grey ashy "A_2" horizon of considerable thickness, often somewhat speckled with reddish-brown specks of limonite (bog iron). Below the "A_2" horizon is generally a dense heavy "B" horizon composed of the fine clays which have leached from the upper layer. This "B" horizon may become more or less impervious, and the over-lying "A_2" horizon may develop into a glei horizon or plane of saturation. These soils are often very deep, and as the lime is invariably removed by the downward leaching processes they are generally acid throughout. (See fig. 32).

While the above are the main characteristics of the swamp podzols, they are quite variable. In many cases surface soils from adjacent lands may be washed in and deposited on the surface. Because of the low position in which

they are found, and the presence of the dense compact horizon which arrests the downward movement of water, they are not suitable for the production of agricultural crops. Their best use is for the production of timber or hay.

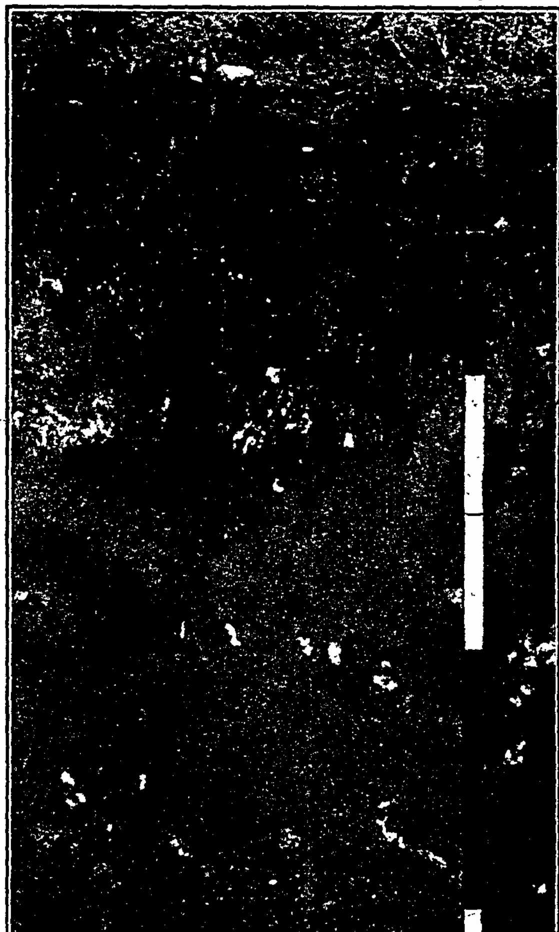


FIGURE 33
Salinized (or white alkali) soil profile, showing nests of gypsum crystals and saline concretions.

3. Meadow Soils

Meadow soils are the soils found in the depressions chiefly in the black soil region, although they may occur both in the timbered or the grassland regions. These soils have been formed under the influence of periodic excessive amounts of water. The surface soils may be very variable. They may have a layer of muck on the surface or the muck may be absent. The dark surface horizon, however, is generally shallow and quite high in organic matter. The subsoils are characterized by grey, blue-grey and mottled colors, more or less speckled with iron or limonite concretions (bog iron). The reddish-brown to yellowish-brown iron concretions in these soils are invariably found just above the horizon periodically saturated with ground water. The native vegetation usually is swale grasses. Such soils are useful for the production of hay, and if drainage can be controlled many of them can be reclaimed and made into productive agricultural soils. However, periodic flooding is a hazard at all times. Their outstanding problem is drainage; they invariably occur in the somewhat depressed or flat positions.

4. Alkali Soils

The so-called "alkali soils" occur in Manitoba as local soils throughout the grassland region, and to a considerable extent in the southern and western portion of the Rendzina soil zone.

There are three different types of soils formed in the process of alkalinization which should be discussed together under this heading. These three types are so different that not only should their characteristics be recognized, but they should be designated by different names. The best and most descriptive common names for these three soil types are "salinized"[1] soils, "alkalinized"[2] soils, and "degraded alkalinized"[3] soils.

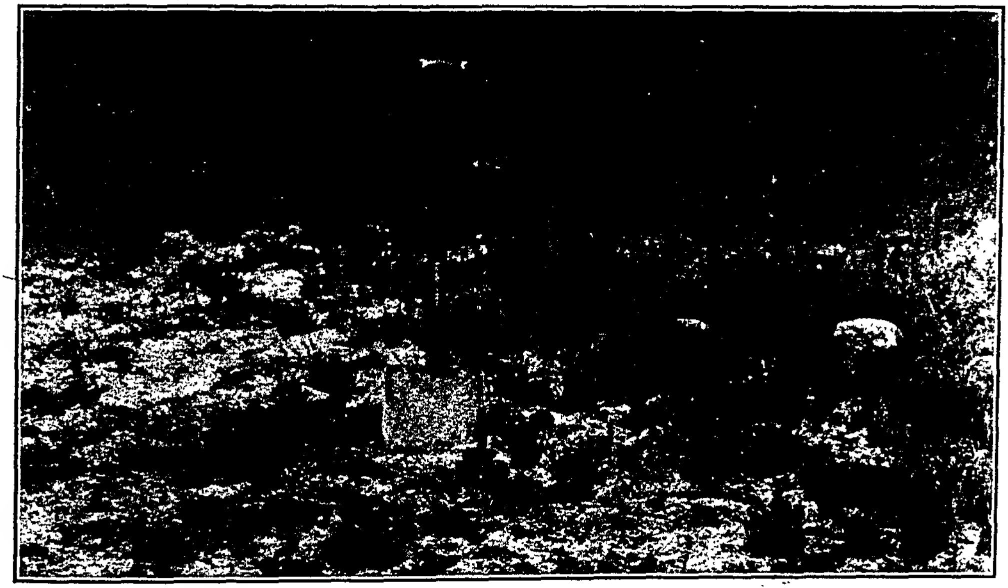


FIGURE 34
Strongly saline soil showing salting at the surface and sparse growths of salicornia and gum-weed.

(a) *Salinized Soils:* The salinized soils (often referred to as "white alkali soils"), are those which contain excessive amounts of soluble salts. In Manitoba, the saline soils are generally the result of periodic swamping with water containing soluble salts. In some cases this swamping is due to the periodic rise of ground water, and in other cases it is due to the accumulation of seepage or run-off water from adjacent alkali-bearing rocks. (See fig. 33 and fig. 34).

The saline soils are usually greyer in color than the adjacent well drained soils, the greyish color being due to the salt coating on the soil particles. Saline soils may easily be recognized by the incrustation of soluble salts on the soil aggregates when they are dry, or by the salt concretions that occur either as streaks or veins in the hollow root channels and soil pores, or by the presence of gypsum crystals at varying depths in the soil profile. The

[1]Solonchak
[2]Solonetz
[3]Solod

higher up in the soil profile the gypsum crystals occur, the more concentrated the soil solution will be. The presence of saline tolerating vegetation, such as salicornia, wild barley, maple-leafed goose-foot, gum weed, and agropyrum grasses with glaucous and bluish-grey leaves also is a good indication of saline soils.

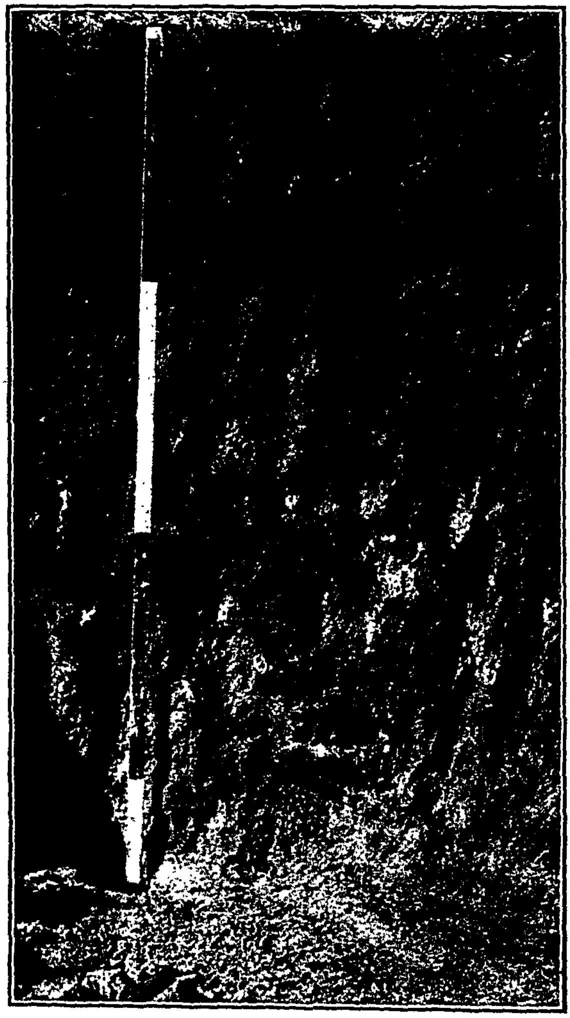


FIGURE 35
Alkalinized (or bad-structure-forming alkali) soil.

The concentration of soluble salts in the saline soils will vary to a marked degree. Occasionally a sufficient concentration of salts may be found to inhibit the growth of plants. Such concentrations, however, are rare in Manitoba. A slight concentration of salts is sometimes found in the intermediate positions in the prairie region where they are found in association with the occurrence of root rot in grain. The salts which are most common in the saline soils of Manitoba are sulphates of magnesium and calcium. Sodium salts appear to be rare. Soils with sulphatic salts distributed through the profile are the most toxic. Carbonated meadow soils are quite common. These soils usually show a grey appearance from the presence of excessive amounts of lime carbonate rather than of toxic salts, but such soils may show lack of crop vigor because of the low availability of phosphorus that is often associated with the high-lime condition.

Saline (or white alkali) soils are problem soils. When the concentration of soluble salts is high, plant growth is retarded and the strong concentration of the soil solution interferes with the normal intake of water and of nutrients by the plants. The reclamation of such soils is too complex to be dealt with in this treatise, but it may be noted that such soils may be classed as either problem or sub-marginal soils.

(*b*) *Alkalinized* (*or Bad Structure-Forming Alkali*) *Soils:* Alkalinized soils are sometimes called "black alkali" soils. They are found in association with saline soils, often in the intermediate position. In Manitoba they develop from saline soils when (due to a change in drainage), the soluble salts have commenced to leach down to lower levels in the soil profile. When the salts are removed down to lower parts of the profile and the concentration of electrolytes in the upper part of the profile becomes low, the clay and the soluble humus in the upper part of the profile become dispersed. The dark colored soluble humus and clay become mobile, and the humus and clay move downward in the soil profile, forming a compact, tough "B" horizon underlain by lime carbonate, gypsum and soluble salts. (See fig. 35).

A typical soil of this type will show a dark colored, black to greyish-black "A" horizon, with platy or diagonally platy structure. These structural aggregates have a dull appearance and a harsh and hard consistency when dry. Under the "A" horizon is a prismatic "B_1" horizon which is dark colored. The prismatic aggregates may be six-sided and flat on the top in their early stages. As these prismatic aggregates occur at about plow depth, and as they are very hard and intractable when dry, such soils are difficult to plow. The draft of tillage machines is increased. When plowed, such soils become hard and cloddy and intractable to work.

Below the "B_1" horizon is a "B_2" horizon, either cubical or nut-like in structure. These structural aggregates are more or less coated with the black tar-like soluble humus which has moved downward from the "A" horizon. Below the "B" horizon lime and gypsum concretions generally occur, and soluble salts are common in the "C_1".

The heavy "B" horizon of these soils swells when wet, and becomes more or less impervious to water, so that water may be ponded on the surface, or the soils may be temporarily saturated in the upper portion. Such soils are often spoken of by farmers as "gumbo soils."

Sometimes the "A" horizon of these soils has been removed by wind, giving rise to the condition known as "burn-outs," but which would more correctly be termed "blow-outs." These blow-outs result when the "A" horizon becomes powdered by desiccation in dry periods, or by wetting and drying, and freezing and thawing. The powdered material which results may be blown off by wind, and the hard, intractable "B" horizon is then exposed. Such spots appear as small pothole-like depressions.

Alkalinized soils occur as local soils on lands which were formerly salinized. They often occur in rings around saline sloughs and depressions, but they may occur as fairly extensive areas, thus giving rise to inferior local soils.

It should be noted, however, that soils which occur naturally as saline soils in Manitoba may or may not be converted into bad structure-forming alkali soils when drainage is installed. The salinized (or white alkali) soils are

invariably friable and granular, and whether they develop into bad structure-forming alkali soils or not will depend upon the kind of soluble salts present. Hence, saline soils should be thoroughly investigated before any extensive reclamation projects are undertaken.

Because of their structure, alkalinized soils are difficult to work, but they may be made to produce fairly satisfactory grain crops if they are continually supplied with organic matter and are kept free from swamping by drainage water. Such soils invariably require the addition of organic matter as well as fertilizer treatment to put them into good productive condition.

FIGURE 36
Degraded alkalinized soil. Salts have leached to lower part of the profile and white capped columnar "B_1" horizon is well developed.

(c) *Degraded Alkalinized Soils:* Degraded alkalinized soils do not occur extensively in Manitoba. Insofar as is known, they may be found as small islands in association with the alkalinized soils. This type results as a later stage in the development of the leaching out of soluble salts. They are characterized by a grey ash-like more or less platy "A" horizon; a round topped columnar "B" horizon, and a dense, compact cloddy to amorphous "B_2" horizon. Gypsum and lime carbonate concretions are common below the "B" horizon. (See fig. 36).

The degraded alkalinized soils are generally acid in the upper part of the profile and are low in fertility. On account of the tough intractable "B" horizon, they tend to hold water in the upper part of the profile. In the virgin condition the vegetation appears sparse on such spots, and when the sod is turned over, the "B_1" horizon looks like a nest of eggs when looked at from above.

In general, it may be stated that salinized (or white alkali) soils occur over sufficient areas in the prairie region of Manitoba to seriously reduce the agricultural value of the lands where they are found, but more especially in the bed of Lake Agassiz and other parts of the grassland region. Bad structure-forming alkalinized soils with one or two exceptions occur naturally as small islands, although there are some fairly extensive areas of weakly alkalinized soils in the Red River Valley which have developed as the result of the installation of drainage.

CHAPTER 5.

SOILS IN RELATION TO PLANT GROWTH

In the foregoing pages the regional and local soils occurring in Manitoba have been described. The morphological characters expressed in the soil profile are the result of the environment, and of the soil-forming processes that are operative as a result of the environment. Hence anyone who works extensively with soils in the production of agricultural, horticultural, or forestry crops should be familiar with the soil morphological characters and the conditions under which they are produced. This knowledge enables one to resolve the environmental conditions from an examination of the soil profile.

The functions the soil plays in plant production may be enumerated as follows:

1. The Medium for Root Development

The soil is the medium in which seeds germinate and in which the plant develops its roots or intake system. As most field crop roots extend down to a depth of three to four or more feet, and as tap-rooted crops and tree roots may extend many feet into the soil, it is of prime importance that in selecting soil for the growth of any crop that there must be sufficient depth of soil in which the plants may develop their root or intake system. The texture, structure, and the consistency of the soil also affect root development; and the texture, the structure, and the amount of organic matter determine the water-holding power of the soil. These factors affect plant root development.

2. Source of Water

The second function of the soil is to supply the plant with water. The water which plants obtain as soil solution must first enter the soil from above as precipitation. The topography, vegetative cover, and the porosity of the soil determine how much water will enter into the soil, whereas the texture or size of the particles and the organic matter content will determine how much of the water which enters the soil will be retained. Thus, although the climatic conditions may be favorable for plant growth from a vegetative standpoint, soils from which there is a great deal of run-off, and soils which are sandy, gravelly or light in texture, will be droughty soils, but more especially so in the prairie regions. (See Appendix II).

3. Source of Nutrients

The third function of the soil is to supply the plant with all the nutrients needed, with the exception of those elements which the plant receives from the air. In general, it may be stated that the regional soils of the dark brown-black earth transition, the black earth soils, the northern black earths, and the black earth soils under woodland invasion in Manitoba, are naturally highly fertile soils. The dark color of these soils indicates their high organic and nitrogen content. The presence of a lime carbonate horizon in the profiles of these soils indicates that leaching is not a factor. Thus, high levels of nitrogen and potash are common in the soils of the regions just mentioned. Where the organic matter has been depleted by erosion, however, low nitrogen levels become a limiting factor.

The total amount of phosphorus is generally satisfactory in most of the dark colored soils. Nevertheless, although these soils are naturally highly fertile, experiments have shown that responses can be secured by drilling in small amounts of phosphate and small amounts of nitrogen along with the grain crops because of the low availability of these elements in the early spring.

The results secured from fertilizer experiments in which fertilizers were drilled in with the wheat in the grain producing area of Manitoba are included to illustrate this point in Table III.

TABLE NO. III—EFFECT OF DRILLING IN FERTILIZER WITH WHEAT IN MANITOBA
Three-Year Average Results, 1929-1931

District	Mean Yield of All Check Plots	Increase in Per Cent.			Standard Error
		With Nitrogen	With Phosphate	With Potash	
	Bushels	Per Cent.	Per Cent.	Per Cent.	
Boissevain-Reston Area*	18.1*	1.58	18.39	—1.33	0.807
Brandon to Elkhorn Area	18.1	1.40	19.04	1.00	1.594
Minnedosa-Roblin Area	20.8	3.04	20.80	0.87	1.014
Killarney-Manitou Area	14.4	5.22	18.45	—1.16	3.038
Red River Valley Area	20.9	8.51	19.49	—0.50	0.878
Carman to Brandon Area	18.8	8.24	14.46	—0.80	1.206
Eden-Norgate Area	20.6	8.78	22.19	—0.20	1.685
Dauphin Area	18.8	12.75	24.38	3.41	1.231
Swan River Valley Area	21.8	13.23	19.38	8.85	3.326

*Two years only.

Reference: Ellis, J. H.: "Zonation for Fertilizer Requirement in the Northern Prairies." Scientific Agriculture 15:2 (Page 96-109) (1934).

The soil zones in Manitoba where low natural fertility is a limiting factor are the Rendzina soils, the grey-wooded soils, and the podzols.

Rendzina Soils: In the Rendzina soils, which are developed on lime-stone parent material, the phosphorus is either low or of low availability because of the excess of lime. Where low yields and lack of thrift in the crops on the high-lime

soils are observed, striking results can be obtained by the use of phosphate. Many of the soils of the Inter-lake region, which have been considered by many people as inferior, can be made into productive soils merely by the judicious use of phosphate and nitrogen fertilizers, but with some horticultural crops lime induced chlorosis, or low iron intake is a factor.

Grey-Wooded Soils: The grey-wooded soils are low in organic matter, low in nitrogen, and often low in available minerals. However, on account of the favorable moisture conditions these soils can be made fertile and productive by the addition of organic matter and by the addition of the necessary fertilizer elements.

Podzol Soils: The podzol soils are frequently low in natural fertility. As they are more suitable for livestock and mixed farming rather than for the production of grain, their naturally low fertility can be corrected by good husbandry. The podzols are examples of soils that can be improved by a system of cultivation that includes the growing of grasses and legumes and the use of manure and fertilizers.

4. Soil Reaction

From the standpoint of production of crops, in addition to providing root room, and supplying the plant with water and nutrients, the soil must have a favorable reaction. While most agricultural plants will thrive in slightly acid soils, the soil should not be too acid. Moreover, if the soils are too strongly alkaline the growth of many plants will be inhibited.

Except for the podzol soils in Manitoba, strongly acid soils are rare. It has been pointed out that one of the characteristics of nearly all the soils in the organized portion of Manitoba is the presence of an horizon of lime carbonate accumulation within the soil profile. Such soils do not develop strongly acid conditions. Hence the use of lime for the correction of acidity is either not needed or of doubtful value on the present agricultural soils in Manitoba. As very little agricultural development has taken place in the podzol belt in Manitoba, the use of lime to correct acid reaction has not been given any serious attention.

On the other hand, in portions of the Rendzina area and in the prairie sections of the province, local soils are found that are alkaline in reaction. The alkalinity of the soils which contain soluble salts in the prairie region, however, is rarely high enough to inhibit the common agricultural crops, but it may be sufficiently high to interfere with normal growth. Some difficulty has been observed in the production of such horticultural crops that originated in acid soil regions, so that lime induced chlorosis is a local problem. The fertility problem which arises in this connection, however, is more important to the home gardener in the city and to the horticulturist than it is to the farmer producing the regional crops grown on Manitoba farms. The problems in this connection require investigation.

CHAPTER 6.

MAJOR SOIL PROBLEMS

In a report dealing with the soils of Manitoba, reference should be made to some of the major soil problems and their solution. The major soil problems in the organized portion of Manitoba include:

(1) The Combating of Drought.

(2) The Control of Erosion by:
(a) Wind, and (b) Water, and

(3) The Retiring of Sub-Marginal Agricultural Lands Back to Grass or Forest.

The maintenance of satisfactory fertility levels, the establishment of satisfactory physical conditions, the reclamation of alkali soils, and the problems of drainage, etc., are examples of local soil problems which require specific and local treatment that need not be dealt with in this report. The combating of drought, in the prairie regions, and the control of erosion by wind and water on all the arable lands, however, are two major problems which require concerted action if the soils of Manitoba are to be kept productive. To these two problems must be added a third, namely, the retiring of sub-marginal soils to grass or other perennial vegetation, so that they may play a more useful part in production, rather than be a means of aggravating the financial problems of direct relief.

The three major problems of soil drifting, soil erosion, and the retiring of sub-marginal lands to grass, are more or less inter-related. They are introduced here to stress the need of soil and water conservation for agricultural permanence and for judicious land use.

1. The Combating of Drought:

As pointed out in the discussion of the soil zones, droughts are common and severe in Manitoba in the dark brown-black earth transition soils. They may occur occasionally in the black earth and in the northern black earth zones, but in this case they are not of such long duration or of such great severity. They are rare, but not unknown, in the other portions of the province. In general, it may be stated that all the soils of the grassland region are more or less subject to irregular and intermittent periods of atmospheric drought.

The amount of water which a region receives in any year depends on factors which are out of the control of man. The only approach to the combating of drought is through the conservation of the water received. Water conservation implies the judicious use of water with the avoidance of waste, or, in other words, water conservation is the intelligent organized control of the available water received, and its storage for maximum utilization for

intelligent use, as opposed to inefficient use and waste. An all-round policy of water conservation for the alleviation of drought requires action both by the state, by the community, and by the individual. Although the conservation of the regional supply of water is the duty of the state, it must be recognized that no amount of water storage or waste control will put water back into the soils of a particular field from which water has been removed by run-off or seepage. The control and storage of water must start on the field where the water falls.

This fundamental fact may be emphasized by pointing out that if the soil and subsoil of a particular field is powder dry, the crops on this field will suffer from drought even though all the water which may have run off this land is ponded into a Government constructed reservoir on the next section.

In a systematic conservation policy, Government activities should be directed towards maintaining and extending the forests for water conservation where trees can be grown, on the higher altitudes, on the slopes of ravines, on run-ways and on waste lands; to the control by check dams of the head waters of streams, and to the impounding of run-off waters by dams and reservoirs; to the control of stream flow; and to the organization of community schemes, etc. An earnest consideration of an organized water conservation policy is commended to the Government for action. At the same time the adoption of water conservation practices by the individual is the first essential step in the combating of drought on the arable lands.

In the soil areas which are subject to drought, the farm operator always should keep in mind the following objectives, all of which have to do with the conservation and use of water:

(a) *The Production on the Farm of as Much of the Subsistence for the Farm Family as Possible:*

This involves the production of a garden and the keeping of sufficient stock for home use, thus reducing the cash outlay for necessities in drought years when there is little or no cash return. This necessitates provision for an adequate supply of water.

To aid in ensuring this objective, the water conservation work that should be largely developed is the installation of dug-outs in retentive soils, or of individual dams in run-ways to impound run-off waters for domestic or stock use, and for the irrigation of the garden. The assisted dug-out and water development policy initiated under the Prairie Farm Rehabilitation Act programme by the Federal Government is an admirable project which is contributing to this end, but it requires initiative on the part of the individual if maximum advantage is to be obtained. As a general rule, the individual farm owner has not taken sufficient advantage of this scheme. The assisted policy should be supplemented and extended by the initiative of the individual.

Instead of building a dug-out merely of the size covered by the Prairie Farm Rehabilitation Act grant, a dug-out should be large enough to ensure a good reserve supply of water, so that the water may be used to irrigate a garden. Where the dug-outs are excavated by drag lines, the excavated earth is dumped as spoil banks along the edge of the excavation. These spoil banks should be removed from the edge of the dug-out and used for the construction of a low dyke (one or two feet high) around an area immediately adjacent to the dug-out, so that the space between the dug-out and the raised dyke can be used for a garden. The unsightly spoil banks of earth from the dug-out can thus be made to serve a useful purpose. The low dykes should be seeded down to grass, and wind breaks of caragana should be planted on the outer side. A boxed check and water gate should be constructed in the dyke so that the surplus water can be controlled without injury to the dyke. By following this procedure, the waters which run into the enclosure in the spring that are more than sufficient to fill the dug-out can be used to give the land which is being used for garden an irrigation of several inches. A thorough wetting of the ground in the spring, when sufficient water is available, will thus ensure a garden which is moist at the beginning of the season. If the dug-out is of sufficient size, the water may be used periodically for the irrigation of the garden by the installation of a pump operated by engine or wind-mill. In some cases, especially where water is not available from wells, the installation of a second or reserve dug-out is worthy of consideration.

(*b*) *The Provision for Subsistence for the Necessary Livestock:*

The production of feed for livestock in the drought area also is determined by water. It requires the production of both winter feed and pasture, as well as water for the stock. During the recent long drought period in southwestern Manitoba, corn, millet and winter rye in most cases, gave some returns even though most grain crops were a failure. The acreage devoted to the production of feed on the average farm in the plains area in Manitoba is very inadequate, and while sweet clover and grasses may be sown when soil moisture is favorable and grasshoppers are not a menace, years may be expected when clover and grasses will fail for various reasons. Hence an acreage of corn, millet and winter rye should be sown each year, sufficient to ensure some feed, and preferably in quantities that will ensure a carry-over as cured feed or silage. To produce such feeds moist soils are essential. To avoid the shipping in of feeds, which someone has to pay for with cash, it may be necessary, during dry periods, to grow these crops on fallow. The principle of using the limited soil water available in the soil for the production of subsistence should be given first place, in preference to the production of cash crops, during dry periods.

The most efficient use of water on pasture depends upon the location of the pasture in relation to topography. If the pasture is level, very little can be done in regard to water control. On pasture from which there is run-off,

the plowing of contour furrows at various intervals across the field and the installation of spreader dykes may be used to retard run-off and to get more water into the soil.

(c) *Provision for the Combating of Drought on the Cultivated Fields:*

For the combating of drought on cultivated fields in which the soil texture favors the retention of water, four principles should be kept in mind:

I. The prevention of run-off from the surface and the getting of all the available water into the soil from above.

II. The holding in the soil of as much water as possible until required by the crops which are to be grown.

III. The planning of the fallow frequency so that crops are sown only when a reasonable supply of soil moisture is present.

IV. The prevention of the surface of the soil from drifting during the summer fallow or moisture storage period.

I. The first objective can be secured during the fallow year by keeping the soil receptive and porous on the surface.

This involves the practice of suitable fall and subsequent summer cultivation so that the water from precipitation may penetrate, and so that the run-off may be reduced to a minimum. (A common fault in fallow management in the dry parts of Manitoba is to delay the work of the summerfallow until too late in the summerfallow year. Advantage should be taken of the fall rains prior to the summerfallow year and of the spring rains in the early part of the fallow season).

If soils are to be kept porous and receptive to water it is essential that attention should be given to the establishment and maintenance in the soil of a high level of organic matter. It is also important that as much of the snow as possible be held on the fields by the use of field wind breaks and trash cover. As a further aid in checking run-off, and thus increasing the water penetration on soils which have an appreciable fall, such practices should be initiated as the construction of broad-base terraces, basin listing, and the cultivation with the contours rather than on the square, or up and down grade. The use of buffer strips of grass on the contours, and the construction of low spreader dykes may be used as aids. Ridge cultivation and the maintenance of a well-aggregated condition at the surface are the practices which should be used on smooth level lands.

II. The second objective can be secured by preventing weeds from using undue amounts of water from the time one crop is harvested until the time the next crop is sown. This will ensure that the water that penetrates into the soil will not be used by excessive growths of undesirable plants. Dead weeds on the surface aid in the conservation of water, but living weeds exhaust the soil water supply.

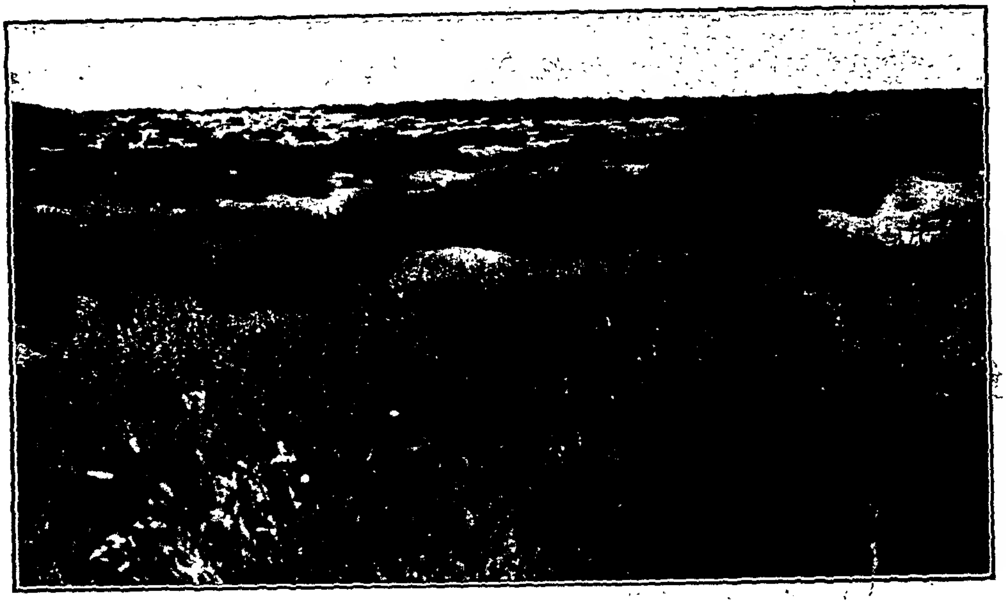


FIGURE 37

Blow-outs, sand banks and Russian thistle on a former sandy loam soil in the Souris basin. Photo taken August, 1937, when soils less injured by drifting produced fair crops. This land should be retired to grass and clover.

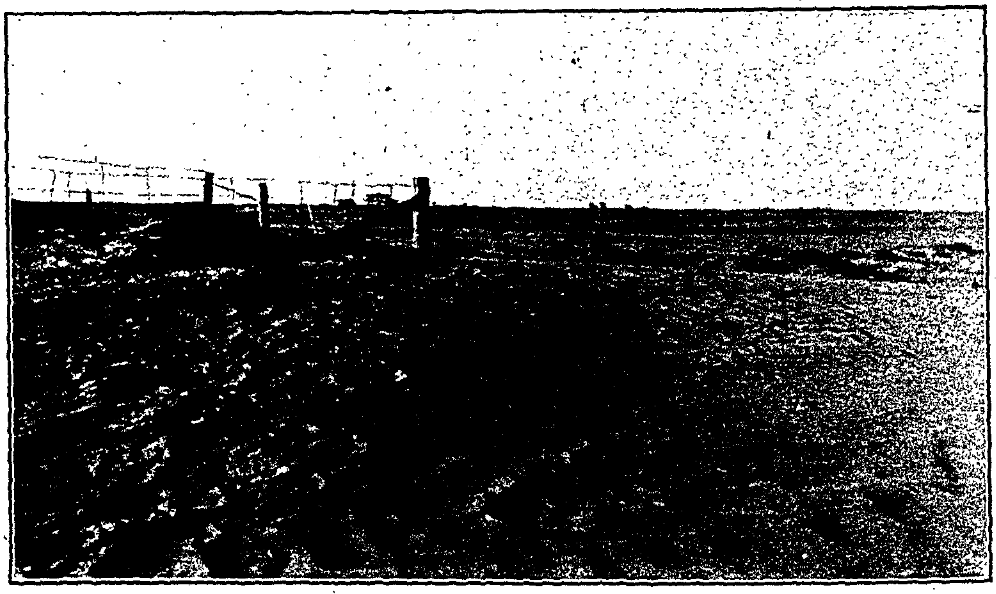


FIGURE 38

Abandoned because of soil drifting. Elva district. The result of attempting to grow wheat with fallow on light, sandy loam soils for too long a period.

III. The third objective can be achieved if a field examination of the soil is made in the spring by each farm operator. The condition of the subsoil, whether moist, intermediate, dry or powder dry, can be ascertained from such a field examination. Thus, a field should be cropped or summerfallowed, according to the moisture condition revealed by such an examination.

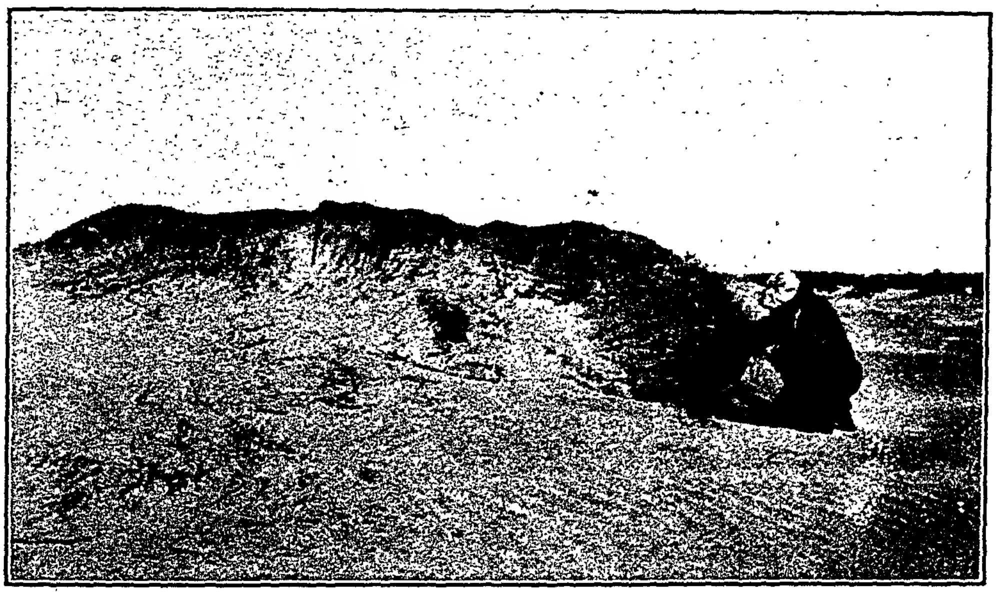


FIGURE 39

The "desolation of ruination." Sand hummocks and blow-outs. The result of the wrong type of land utilization of a sandy loam soil. (Scarth district).
(Photograph, courtesy of Prof. C. W. Lowe).

IV. The fourth objective may be achieved if the soil has a favorable degree of aggregation, or structure (and if the weather conditions are not adverse), by the combination of the following practices:

(a) The maintenance of a rough, cloddy or ridged condition, or the maintenance of a trash cover. If the soil is not in a favorable structural condition, that is, if it is powdered or single grained, a trash cover must be applied or a cover crop must be grown to provide trash. In the latter case some soil moisture, which should be conserved for the crops, has to be sacrificed for the production of the trash cover crop.

(b) The reduction in the size of the fallow fields by some form of stripping with intertilled or other crops (corn, etc.).

(c) The use of field wind breaks of tall growing annual crops, or of caragana hedges, to reduce the wind velocity over the soil surface.

(d) The periodic seeding down to suitable grasses to improve the soil structure.

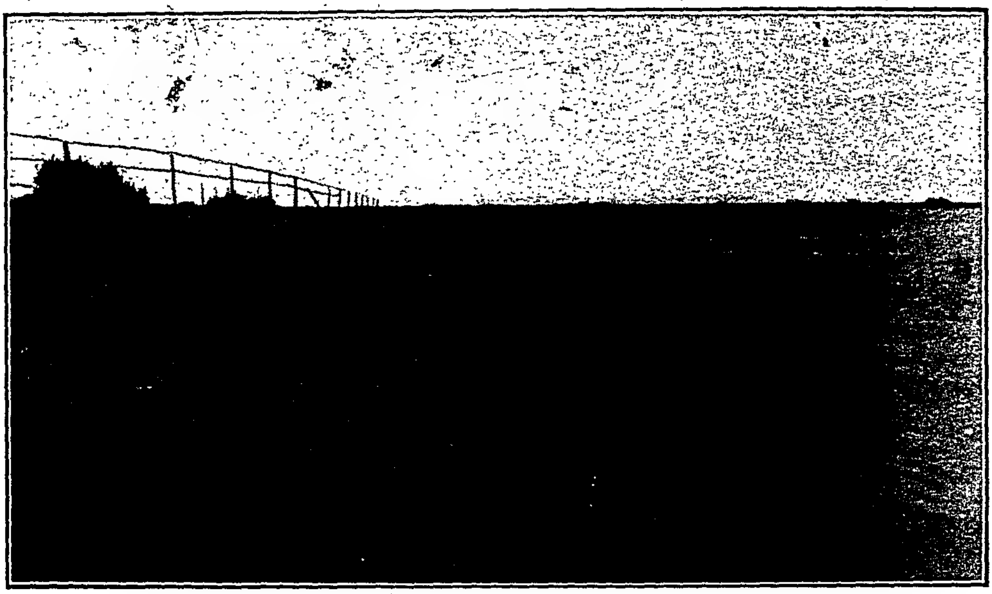


FIGURE 40
Soil drifting on former sandy loam soil near Melita. Two feet of surface soil removed from the field, and carbonate horizon exposed.

FIGURE 41
The effect of drifting on soil developed on boulder till parent material. Fine separates removed; cobbles, gravel and coarse sand left at the surface. (Tilston area).

Summerfallow for moisture conservation should be practised in the prairie regions of Manitoba only on soils which have medium to good water retention capacity. The somewhat lighter textured soils may be handled more satisfactorily by the growing of corn or other fallow substitutes.

Lands on which crop production cannot be assured by the use of the above practices, such as lands with rough topography, or with gravelly and light sandy textures, should not be used for grain production or as arable lands in dry districts. They should be recognized as sub-marginal for this purpose.

2. Control of Erosion

A. WIND EROSION:

Wind erosion is by far the most powerful agent in reducing the fertility of the soils used for the production of grain in Manitoba. This problem is becoming more serious with the passing of the years. A considerable acreage of land has gone out of cultivation from this cause, and unless it is tackled as a major problem, other lands which are still fairly productive will be depleted to such an extent that abandonment will follow. (See figs. 37-42).

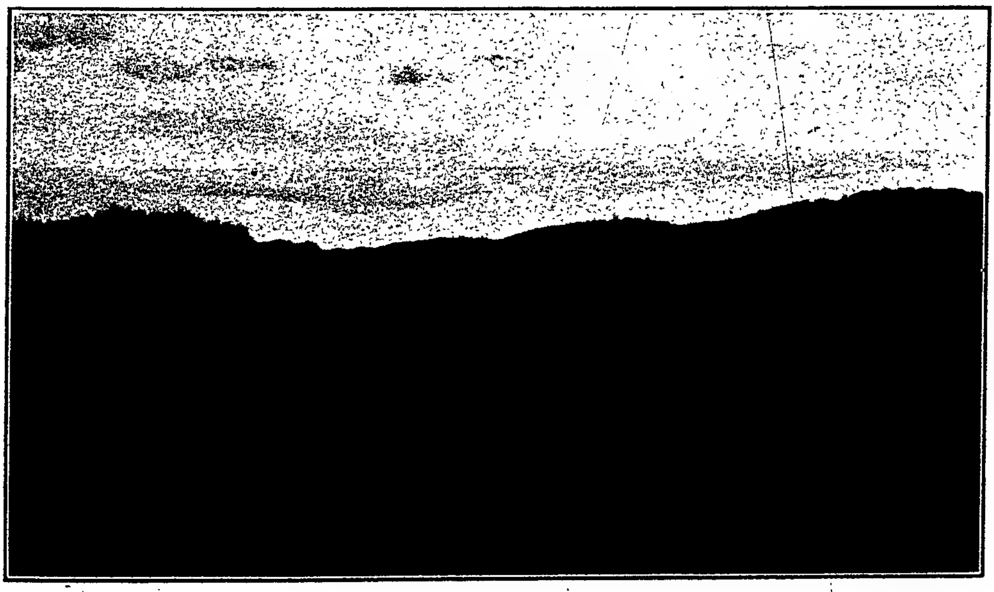


FIGURE 42

The end result of wind erosion. Sand from which all fine material has been removed, continually moving so that native vegetation cannot become established. (Aweme, Manitoba).

In the plains region, soils which were of good sandy loam texture have become coarser due to the removal of the fine materials by wind. Other soils which are fine in texture have had the surface material removed as dust, and, though sand banks may not appear in the fence corners, the thickness of the

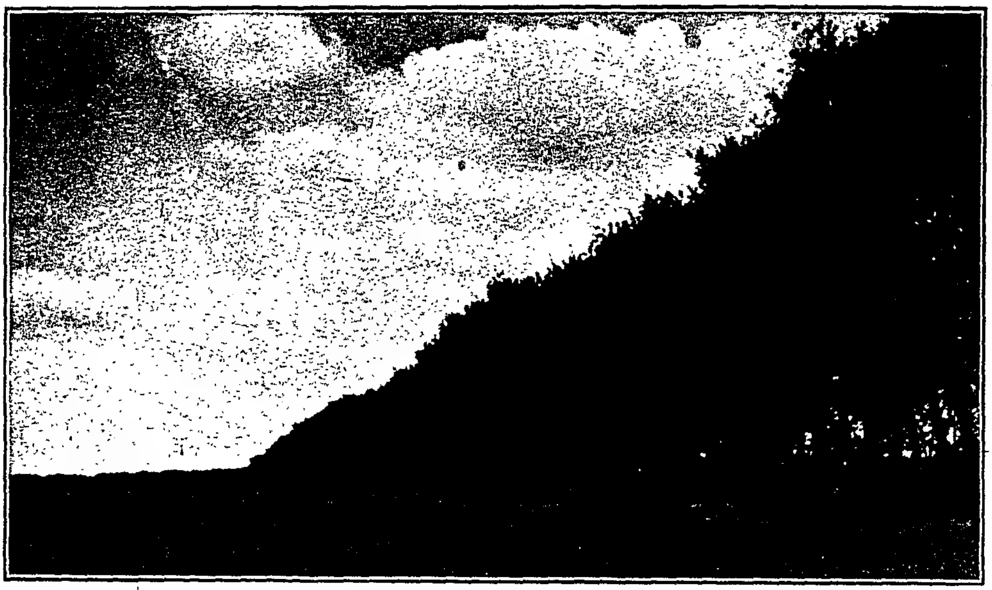


FIGURE 43

Trees planted as field wind breaks. The maples here planted permit wind to get through at the ground level. A better field wind break would have been obtained if caragana, with ash and elm had been used.

FIGURE 44

An ideal field wind break of caragana that has withstood the drought. This species gives ground protection so that injurious winds do not get through.

dark colored surface horizon is becoming less and less by the gradual removal of the soil as dust. On more rolling topography, soil from the knolls and the upper slope positions has been eroded by wind so that in many cases the sub-soil outcrops at the surface. These exposed areas of the less fertile subsoil are increasing in size as years go by. The presence of blow-outs and sand banks, in some of the lighter textured soils which were formerly devoted to the growing of wheat, are evidences of the soil deterioration which is taking place by the action of wind. These various manifestations of the injury to Manitoba soils by soil drifting have profoundly affected the natural fertility, the deteriorating effect of which is accelerated with time.

The main cause of soil erosion by wind is the occurrence of wind of sufficient velocity to move the soil particles. The second cause is the presence of particles or aggregates of such size that they can be either moved by rolling, or lifted by the wind and sustained in moving air currents. The methods for the control of erosion by wind are:

I. The reduction of wind velocity over the surface, or by providing a cover so that the soil is not exposed to wind action.

II. Increasing the size of the soil aggregates.

I. Methods for Reducing the Velocity of the Wind:

(a) *Field Wind Breaks:* The velocity of the wind may be decreased over the soil surface by the planting of field wind breaks of caragana, etc., on the medium to light textured soils developed on lacustrine material in the black earth region. (Fig. 43 and fig. 44).

Large acreages of good fine sandy loam and fine loam occur in the basin of Lake Souris and in the Assiniboine delta, where the ground water occurs from 6 or 8 or to 12 or 15 feet respectively below the surface. The lighter textured soils in these areas have shown considerable injury from wind erosion and many farms have gone out of cultivation from this cause. The better textured soils have stood up against wind erosion for a longer time, but continued annual removal of fine materials is making these soils more and more susceptible to soil drifting. A policy of soil conservation in these soils is of vital importance rather than waiting to adopt a reclamation policy when the soils have been depleted.

On such soils with sub-soil moisture, the use of field wind breaks cannot be too strongly advocated; a vigorous policy of field wind breaks planting should be initiated in order to save these soils from rapid deterioration by wind.

(b) *The Maintenance of a Trash Cover:* In the open plains region the use of a trash cover by keeping the stubble on the top is a valuable aid in protecting the surface from wind injury. Where stubble is too light to be of value, a light sowing of an annual crop either in the spring or fall on the summer-fallow land, and then cultivating the land when the crop is about one foot (or more) high will provide trash where stubble is not available. (See fig. 45).

(c) *The Use of Fallow Substitutes:* On the lighter textured soils of the black earth region the use of corn as a fallow substitute may be followed, especially on the lighter textured lands with moist sub-soils. Corn or sorghum may be planted either in strips or with the rows wide apart to give wind protection by an annual crop, and to provide for the production of feed. On the light textured soils with low sub-soil moisture, black summerfallow should never be practised as a general procedure. (See figs. 46 and 47).

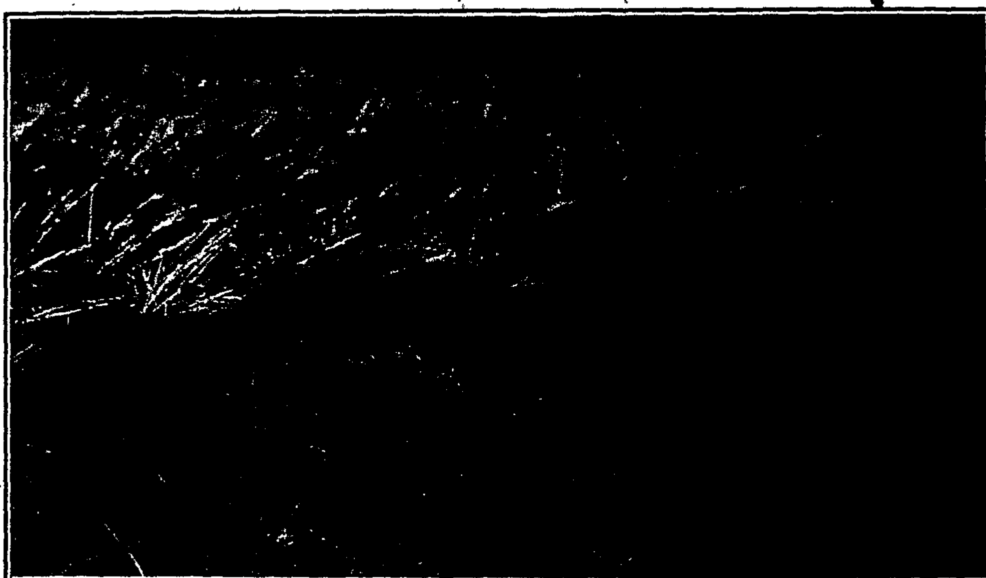


FIGURE 45

Stubble as trash cover, and annual crop sown to produce trash cover for surface protection if soils are liable to drift.

(d) *The Maintenance of a Cloddy Structure:* On the medium-heavy to heavy textured soils the maintenance of a rough cloddy condition by the judicious use of suitable implements at the right time should be practised. Ridge cultivation, and in some cases the use of the lister plow, or lister shovels on the cultivator to give a roughened surface condition, may be followed rather than level smooth cultivation. (No method of cultivation, however, will maintain a roughened condition on bare soils that slack down to a "single grained" structure).

II. To Increase the Size of Structural Aggregates:

Any soil which is powdery or in a "single grain" condition will drift. Large aggregates, on the other hand, are not moved by wind. The longer the time interval from the breaking of the sod the more easily will the soil aggregates break down. The soil structural aggregates are formed by the cementing action of the finer particles (or soil colloids) and by the binding action of grass roots. As the grass roots decompose, the aggregates become weaker and the

FIGURE 46
Corn in drill width rows for surface protection. Thornhill, Manitoba.

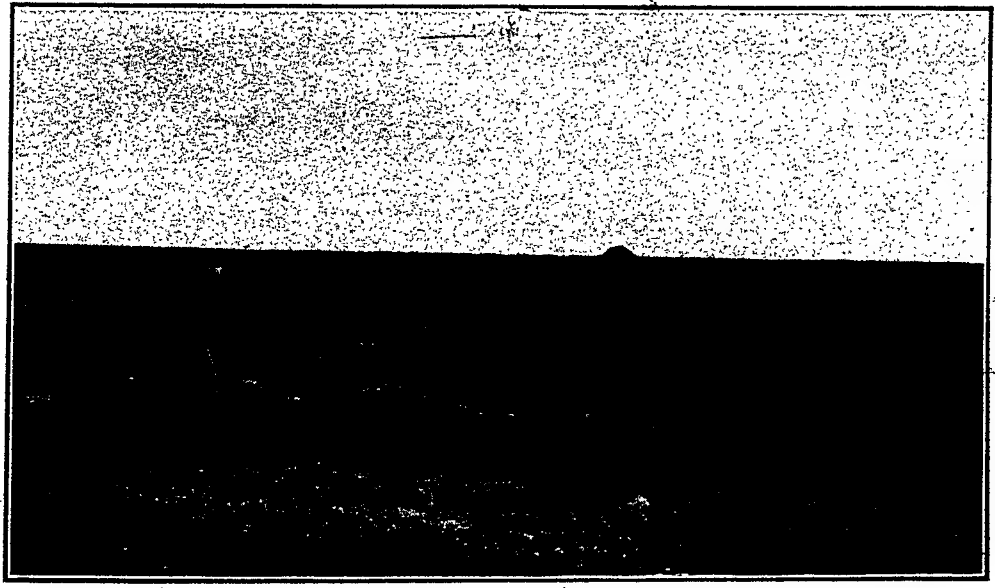


FIGURE 47
Corn in strips for surface protection and for feed. Lyleton district.

soil becomes more susceptible to drifting. When the ability of the soil to form aggregates is reduced, such land should be temporarily retired back to turf-forming grasses. However, it should be noted that on "single-grained" sands from which the fine material has been removed, the seeding down to grass will not cause the development of aggregates that will resist the disintegration by wind. Hence the periodic retirement of the wheat lands to grass should be undertaken before drifting has become acute, and before the fine soil material responsible for the cementing of the soil aggregates has been removed by wind (but especially where the soils have developed on lacustrine sediments).

Figure 48

Sheet and gully erosion north of Turtle Mountain. Six to eight feet of soil deposited at the foot of the slope, eroded from the field in the background.

Soils on which drifting cannot be controlled by the above practices should be retired permanently or semi-permanently to grass or other vegetative cover.

On the lighter textured soils which now show a condition of blow-outs, blow sand piles and dunes, the most practical policy is to permit such land to grow up with Russian thistle and other weeds in the moist seasons. When the weeds have become established they can be used as a nurse crop for the seeding down of winter rye, or grasses and clover, by scattering or drilling in these seeds in the weed growth. Every attempt should be made to get such injured soils seeded down to grass and to use these lands for pasture (or hay).

It should be recognized that the light soils in the black earth and the dark brown-black earth transition zones will only grow wheat continuously for a short period of years, and while the medium-heavy textured soils may be used for the production of wheat for a longer time, the light textured soils can only be used for wheat production for a very limited period.

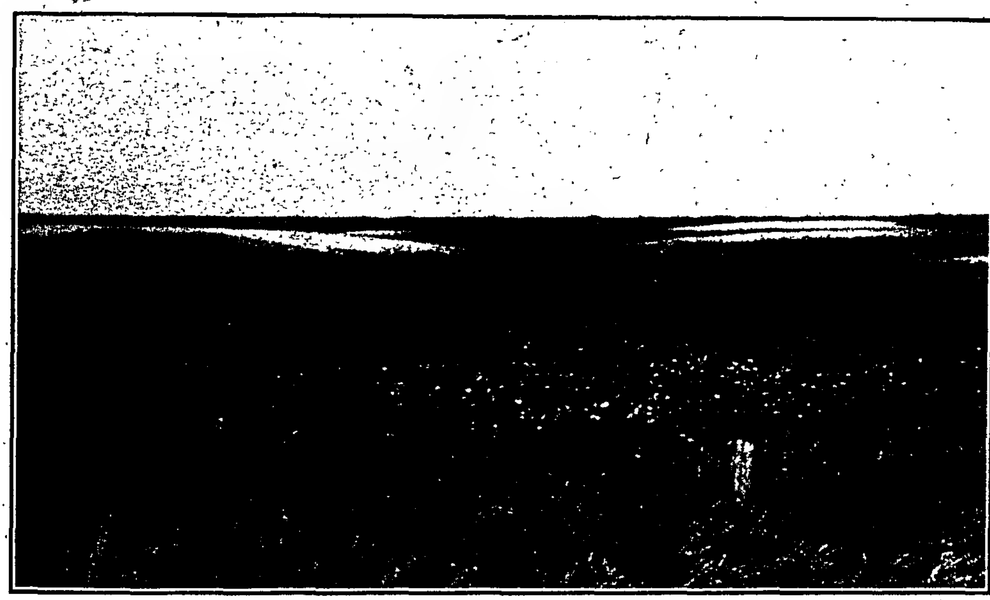


FIGURE 49

Erosion in the Carroll soil association. Surface soil removed from higher positions by sheet erosion and wind. These soils have not worn out, they have washed out or blown away and constitute a challenge to the province for an active soil conservation policy.

It is absolutely necessary from a soil conservation standpoint that the poor wearing capacity of the sandy textured soils of the grassland region should be recognized, and that such land should be retired periodically to grass. The practice of continuing to grow wheat alternated with summerfallow on the light textured black-earth soils is criminal exploitation. A policy of soil conservation of such soils must be adopted or the amount of abandoned land in Manitoba will increase in the near future.

B. WATER EROSION:

Control of Erosion by Water:

The erosion of soil by water is becoming more and more acute in certain soil associations, and under certain topographical conditions. The areas at the present most affected are the rolling lands in the Alexander district, the northern slopes of the Turtle Mountains, the rolling and sloping lands of the Manitoba escarpment, and the sharply undulating and hilly lands of the Bruxelles district. Evidence of the injury which has already taken place can be observed by the thinning of the soil on the knolls, by sheet and rill erosion, by incipient gullying of the slopes, and by the deposition of the surface soil at the foot of the slopes. (See fig. 48 and fig. 49).

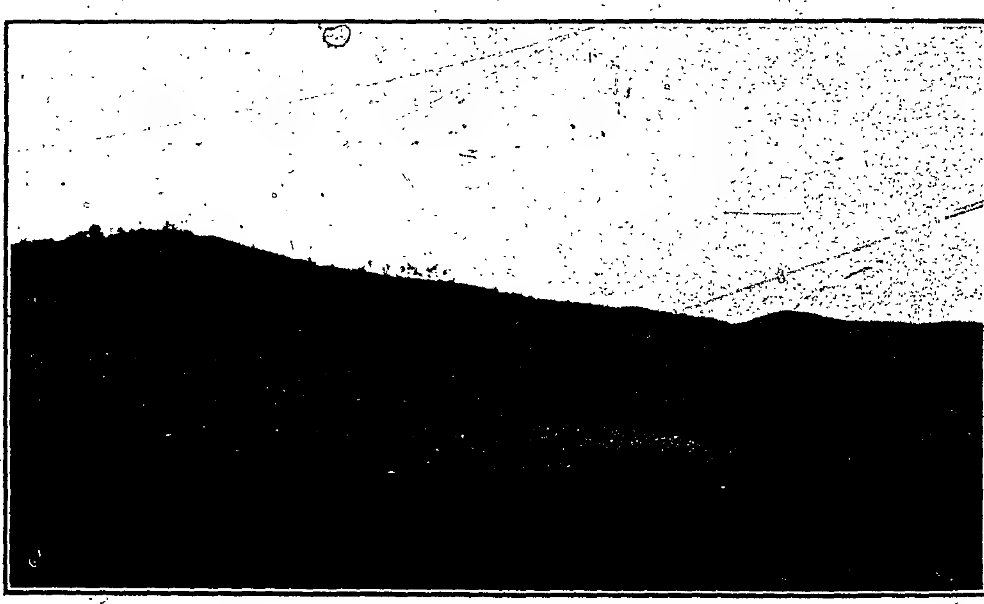


FIGURE 50

Example of the type of topography where special soil conservation practices are essential. The sharp knolls or hills should be kept in forest or grass, and the arable land farmed by a system of crop rotation on the contours with special attention to the practices which will prevent or retard water erosion.

Water erosion, like wind erosion, accelerates with time. Soils which have stood up fairly well against erosion in the years following the breaking of the prairie sod are now showing evidences of this form of deterioration. The degree

of erosion will increase rapidly with the passing of the years, and wherever this form of erosion is observed, immediate steps should be taken to conserve the soil, or in the very near future a considerable increase in the acreage of abandoned land will result. (See fig. 50).

When the soil which took thousands of years to produce is washed from the higher positions, or when the soil profile has become truncated by the removal of the surface soil, reclamation is a costly and a slow process. Prevention is better than cure.

The practices which may be initiated to control soil erosion by water include:

(a) The cultivation crosswise of the slopes, or parallel to the contours, instead of working up and down grade.

(b) The maintenance of a rough, cloddy and porous surface, or the maintenance of trash or crop cover. (See fig. 45).

(c) The basin listing of fallow land on the slopes and hill-sides. (See fig. 51).

(d) The stripping of the slopes with buffer strips of grass at intervals around contours or in the form of "S" strips.

(e) The installation of shallow broad base terraces, and spreader dykes, etc., on the stronger slopes. (See fig. 52).

(f) Contour farming under crop rotation in stripped fields.

(g) The seeding down to grass or forest of the sharp knolls and the steep slopes of ravines.

(h) The sodding of water-ways and the control of the water by the use of check dams, and

(i) The use of crop rotations which include the periodic seeding down to clover and grass.

In the past, little attention has been paid in Manitoba to these methods of preventing soil deterioration. A vigorous policy of soil conservation, individually by land operators, and collectively by agricultural organizations and by the Provincial Government, is urgently needed. The maintenance of the productivity of Manitoba farm lands is vital to the prosperity of Manitoba. The deterioration of the farm lands has been due largely to mechanical causes (i.e., to wind and water action), rather than to the removal of nutrients by the growing of crops. The control of these mechanical sources of soil deterioration is a challenge to the people of Manitoba.

3. The Retiring and Maintenance of Submarginal Lands to Grass or Forest

In a land-use policy it is a fundamental principle that the shallow soils on rough topography, which are droughty because of excessive run-off, and the coarse textured soils which have a low water retention capacity, must be

FIGURE 51

Basin listing of summerfallow in the previous fall to prevent washing and run-off in rolling lands, and to increase water penetration. The furrows should be run with the contours or cross-wise of the slope.

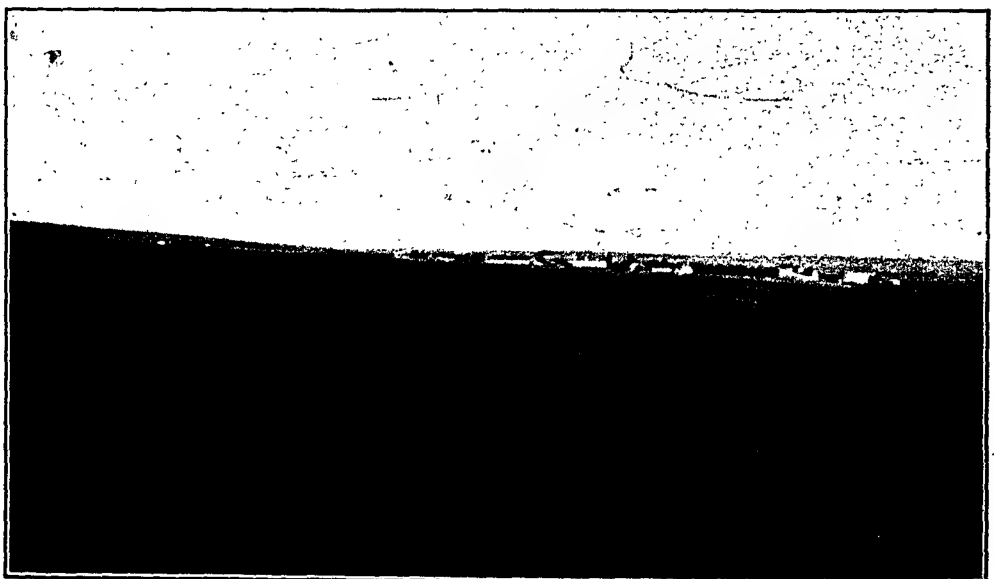


FIGURE 52

Broad base terraces built on the contours to prevent run-off and water erosion, and to increase water penetration. Crops can be drilled over the terraces crosswise of the general slope.

classed as submarginal for general agriculture in dry or semi-arid regions. Attempts to farm such lands in the prairie regions are doomed to failure. Such lands should be maintained as, or be retired to grass and used as range. No attempt at water conservation will ensure the successful arable culture of lands of this type.

During the period of settlement in Manitoba, areas of submarginal lands have been alienated from the Crown. Various attempts to farm these lands have failed and they are now abandoned. Many of these properties have been acquired by the different municipalities through tax sale. To ensure that submarginal lands of this kind are not again sold to cause further disaster, action should be taken by the Government which will ensure:

(1) The seeding down and retiring of such lands to grass or forest for more intelligent land use; and

(2) Provision for the control of such lands by the State so that they will not be broken up as arable land, by ambitious and well-meaning but misguided individuals, during periods of good prices.

One of the uses to which such land should be put would be community or municipal pastures or hay lands. Other uses may be more suited in certain cases. The essential point is that lands which are not suited for arable culture should be so designated, and a provincial policy evolved which will prevent such lands from again being held by private interests for the exploitation of the uninitiated.

The policy followed by the Provincial Government of maintaining the sand dune area of the Assiniboine delta as Forest Reserve should be highly commended. It is very important that an adequate vegetative cover be maintained on such areas. This policy could be extended to include smaller areas of dunes in the Souris basin, where the presence of ground water favors the maintenance of forest growth. This policy of Government ownership and control could be extended advisedly to include the formation of reserve pastures on light textured marginal soils where drifting is a serious menace.

In the Province of Manitoba there is an enormous acreage of crown lands. As pointed out in the foregoing text, very considerable areas of these crown lands have not been taken up as agricultural lands because of the obvious unsuitability of the territory for agricultural settlement. The present provincial policy of holding these lands as public domain for the production of forest and wild life, etc., is a sound policy for which credit should be given. Undoubtedly, areas of land suitable for agriculture are scattered throughout the crown lands, and when economic conditions warrant, pressure will no doubt be instigated to have such areas opened up for settlement. Before any such new lands are opened up for settlement a soil survey of each of such proposed areas should be made to ascertain the probable agricultural value of the soils.

Furthermore, consideration should be given to the advisability of retaining the soils, which are apparently suitable for agriculture, as crown lands under a lease arrangement, instead of alienating them from the crown by sale. Under individual ownership there is no state supervision to curb soil exploitation by the individual. On the other hand, a long-term lease, with provision to ensure security of tenure to the operator of lands held by the Crown, would enable the State to instigate and foster soil conservation practices for the preservation of such lands for the use of future generations.

Throughout the organized territory lands were disposed of by the Crown before the essential facts about the soil were known. Consequently, the misfortunes which followed attempts to farm such lands cannot all be charged to the individual. It would appear advisable that consideration be given to the formulation of a well-thought-out policy, whereby the submarginal lands that have been alienated from the Crown may again be repossessed and held, either by the province or by the municipality, under a land-utilization scheme that will eliminate private ownership, and exploitation, of lands which have been proved unsuited to, or incapable of supporting, independent effort.

CHAPTER 7.

THE MANITOBA SOIL SURVEY

The foregoing report deals in a general way with the information about soils of Manitoba secured from general experience and from information acquired during the progress of the Manitoba Soil Survey. It is presented to give a general concept of the major soil types and their distribution in Manitoba, and to point out the major soil problems. A more detailed study of the soils of Manitoba has been undertaken by the Manitoba Soil Survey.

The Manitoba Soil Survey is financed by the Dominion Department of Agriculture, and by the Provincial Department of Agriculture, in co-operation with the Soils Department of the University of Manitoba. In this connection especial mention should be made of the interest in and the wholehearted support and assistance given to this work by Dr. E. S. Archibald, Director of the Dominion Experimental Farms, without which the progress made to date would not have been possible.

The portion of the province in which this work has been undertaken systematically is located within the boundaries to which the Federal Prairie Farm Rehabilitation Act applies, but at the completion of the work in this region it is proposed to extend the survey to other parts of the province.

The type of survey which is being conducted at present is a reconnaissance survey. That is, the soils are mapped as observed along each road allowance and the boundaries within each section are drawn in arbitrarily. For the

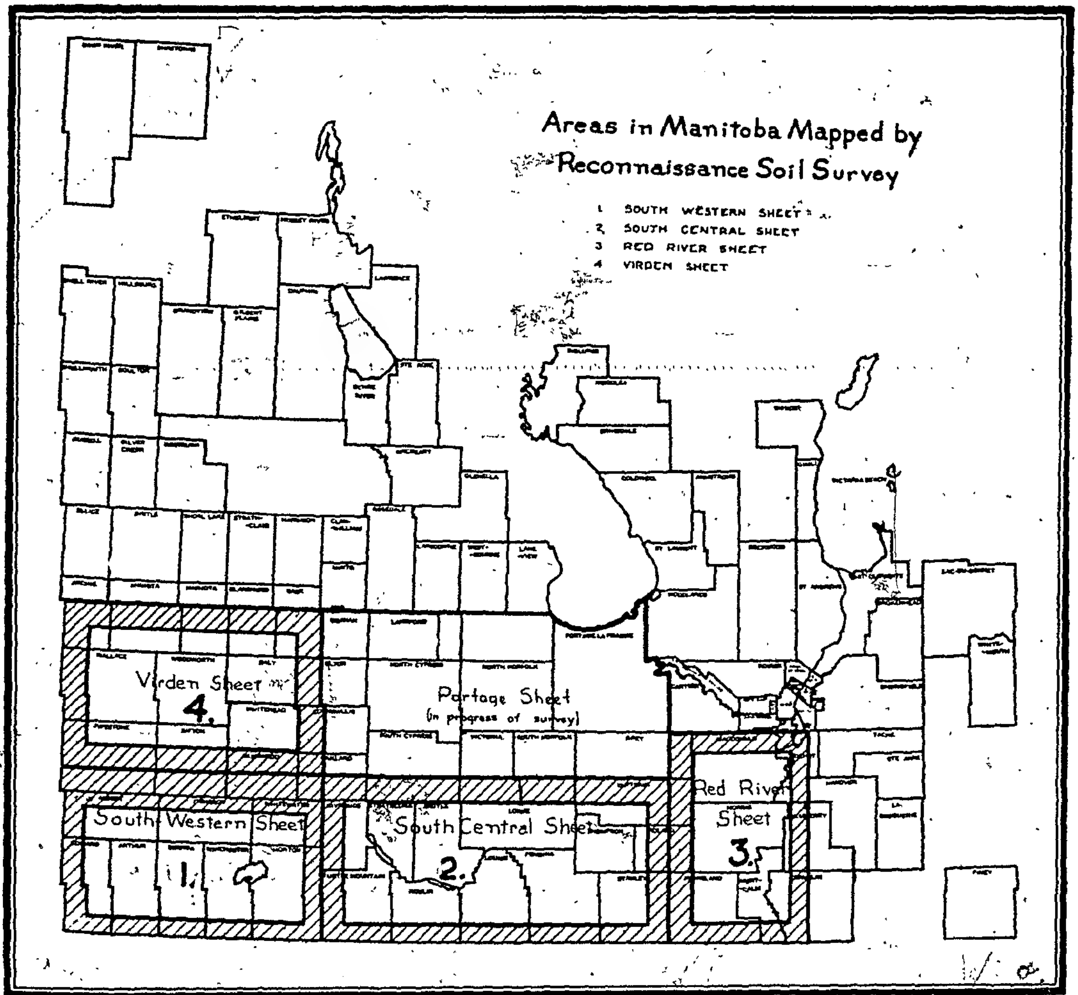


FIGURE 53
Areas in Manitoba mapped by Reconnaissance Soil Survey to date.

prairie region this type of survey is in sufficient detail in view of the type of agriculture followed, as it enables the soil surveyors to see two sides of each quarter-section.

The area covered to date is seen on the map presented as fig. 53. The data obtained in the specific areas are too detailed to include in this report. Separate survey reports and soil maps of each area covered will be published. However, to round out this report and bring the general information up-to-date, generalized land classification sheets have been made from the soil maps for the four areas already covered. These are added to this report. While much of the detail contained on the soil maps has been omitted from these land classification sheets, the latter are self-explanatory and will give a useful generalized picture of the soils found in the southern part of Manitoba.

APPENDIX I.

The Component Parts of a Soil

Soils are made up of seven component parts which may be enumerated as follows:

1. The Skeleton:

The skeleton may be considered as the mineral material derived from the surface geological deposits. In a large measure it affects the soil texture, the water regime, and the reserve amounts of lime and nutritive elements.

2. The Organic Matter:

The organic matter added to soils is produced or synthesized by the higher plants, and this in turn is decomposed by the micro-organisms, so that organic matter exists in the soil in all stages of decomposition. The type of organic matter produced by the higher plants depends upon the species of plants which produce it. For example, trees deposit organic matter as leaf mold *on* the surface, grasses and herbs deposit organic matter between the soil particles *within* the soil.

3. The Fine Materials (sometimes referred to as the "Ultra Clays" and technically known as the "Soil Colloids"):

These are both organic and inorganic, which together with absorbed chemical elements (cations) form the "soil absorption complex." The absorption complex (or soil colloids) are the products of the weathering of inorganic and organic material. Together with the organic matter the colloids constitute the most important components of any soil because their physical and chemical properties determine the structure and fertility of the soil. A soil having little or no colloids would be a skeleton soil.

4. Intrusions and Concretions:

Like the soil colloids the intrusions and concretions also are the result of the process of soil formation. Intrusions may be mechanical due to cracking, shrinkage and subsequent infiltrations, or they may be biological, due to the action of plant roots and burrowing animals. Concretions are chemical accumulations, derived from weathering and precipitated from the soil solution. They may be deposited by downward or upward movement of water. (Sometimes they may be of micro-biological origin).

5. Soil Organisms:

The soil micro-organisms constitute the soil flora and fauna. They include the plant forms known as the bacteria, actinomyces, algae and fungi groups; and the animal forms known as protozoa. To these must be added the more highly organized forms, i.e., nematodes, worms, insects and burrowing animals, etc. The soil micro-organisms play an important role in soil formation. They are responsible for the humification and decomposition of the organic deposits which were synthesized by the higher plants.

6. The Soil Air:

The soil air occurs in the pores or the soil interspaces. It differs from atmospheric air chiefly in its higher carbon dioxide content, derived from the action of the soil organisms and plants.

7. The Soil Solution:

The soil solution is the circulatory system of the soil. It is in a continual state of change, and its movements control the movements of the mobilized and soluble decomposed products of soil weathering. The soil solution supplies plants with water and nutrients.

Soils are not so much sand, silt, clay and organic matter, but complex natural bodies occurring at the surface of the earth where the surface geological deposits are acted upon and influenced by biological activity and climate.

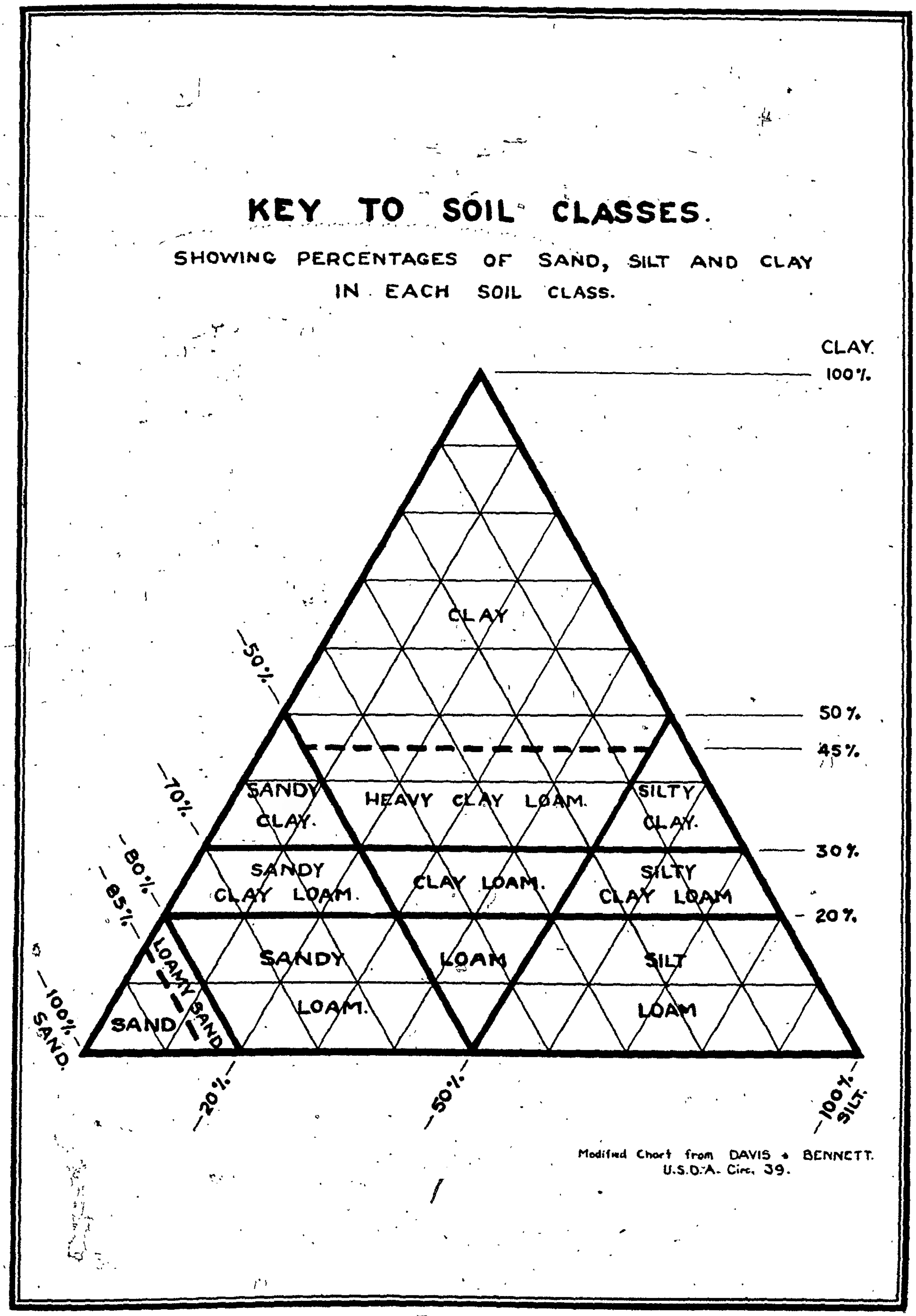


FIGURE 54

Chart showing the proportion of sand, silt, and clay in the various soil classes used in the Manitoba Soil Survey (Appendix II).

APPENDIX II.

Relationship of Parent Material to Soil Texture, Water Retention Capacity, and Lime and Mineral Reserve

The kind of mineral geological deposits play an important part in soil formation. The parent material determines the soil texture, the water retention capacity, and the lime and mineral reserve. The type of mineral deposit also influences soils indirectly through its effect on vegetation.

(1) SOIL TEXTURES:

The term "soil texture" refers to the size of the soil particles and indicates the coarseness or fineness of the mineral material. As soils are made up of particles of widely varying sizes, blanket terms are used to express the relative amounts of the different sizes of particles present in given samples. The arbitrary sizes into which the individual particles are separated in mechanical analyses on the basis of diameter size are termed the "soil separates." The terms used by the U.S. Bureau of Soils and the terms used by the International System are as follows:

U.S. BUREAU OF SOILS SYSTEM		INTERNATIONAL SYSTEM	
Soil Separates	Particle Diameter Size.	Soil Separates	Particle Diameter Size
	Millimetres		Millimetres
Fine Gravel	2 — 1	Coarse Sand	2 —.2
Coarse Sand	1 — .5		
Sand	.5 — .25		
Fine Sand	.25— .10	Fine Sand	.2 —.02
Very Fine Sand	.10— .05		
Silt	.05— .005	Silt	.02—.002
Clay	Less than .005	Clay	Less than .002

The U.S. Bureau of Soils system of classification is the one universally used in North America for the basis of soil classification, but the International System or a combination of the two systems is used in the works for scientific publications.

Soil Classes (or Textural Groups):

As soil textures rarely occur in the field as separates, but as mixtures of the various sized separates, the relative proportion of the various soil separates existing in any given soil is described by a blanket term which is known as "Soil Class." The chief soil classes and the range of each of the soil separates which constitute the various classes are given in Table IV.

The proportion of sand, silt, and clay for the main soil classes used in the Manitoba Soil Survey are shown also in the graphic form in fig. 54.

TABLE No. IV

KEY TO PROPORTIONS OF THE VARIOUS SOIL SEPARATES IN DIFFERENT SOIL CLASSES

UNITED STATES BUREAU OF SOILS SYSTEM

Soil Classes	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay	Maximum available water, in inches, in per foot of soil
	2.0 - 1.0 mm.	1.0 - .50 mm.	.5 - .25 mm.	.25 - .10 mm.	.10 - .05 mm.	.05 - .005 mm.	Less than .005 mm.	
	Lack cohesion; are gritty; particles can be seen by the eye	—	—	—	—	Velvety, and floury feel	Smooth feel, sticky when wet	
SANDS:								
Coarse Sand	35% or more	—		Less than 50%	—	Less than 15%	—	.25″ - .50″
Sand	35% or more	—	—	Less than 50%	—	Less than 15%	—	
Fine Sand				50% or more	—	Less than 15%	—	
V.F. Sand					50% or more	Less than 15%	—	
LOAMY SAND:								
L. Coarse Sand	35% or more	—		Less than 35%	—	15 to 20%	—	.50″ - 1.0″
Loamy Sand	35% or more	—	—	Less than 35%	—	15 to 20%	—	
L. Fine Sand				35% or more	—	15 to 20%	—	
L.V.F. Sand					35% or more	15 to 20%	—	
SANDY LOAM:								
Coarse S. Loam	45% or more	—			Less than 35%	20 to 50%	—	1.0″ - 1.75″
Sandy Loam	25% or more	—	—			20 to 50%	—	
Fine S. Loam	Less than 25%	—	—	50% or more		20 to 50%	—	
V.F.S. Loam					35% or more	20 to 50%	—	
LOAM—SILTY LOAM:								
Loam		30 to 50%	—	—	—	30 to 50%	Less than 20%	1.75″ - 2.5″
Silt Loam		Less than 50%	—	—	—	50% or more	Less than 20%	
CLAY LOAMS:								
Sandy C. Loam		50 to 80%	—	—	—	Less than 30%	20 to 30%	2.5″ - 3.0″
Clay Loam		20 to 50%	—	—	—	20 to 50%	20 to 30%	
Silty Clay Loam		Less than 30%	—	—	—	50 to 80%	20 to 30%	
CLAY:								
Sandy Clay		50 to 70%	—	—	—	Less than 20%	30 to 50%	3.0″ - 3.5″
Clay		Less than 50%	—	—	—	Less than 50%	30% or more	
Silty Clay		Less than 20%	—	—	—	50 to 70%	30 to 50%	

A simplified classification for field use is as follows:

1. *Soils with less than 20 per cent of clay:*

(a)	Over 85 per cent sand	Sand.
(b)	80 to 85 per cent sand	Loamy sand.
(c)	50 to 80 per cent sand	Sandy loam.
(d)	30 to 50 per cent sand	Loam.
(e)	Over 50 per cent of silt	Silt loam.

2. *Soils with 20 to 50 per cent of clay:*

(a)	50 to 80 per cent of sand	Sandy clay loam.
(b)	20 to 50 per cent of sand	Clay loam.
(c)	50 to 80 per cent of silt	Silty clay loam.

3. *Soils with over 30 per cent of clay:*

(a)	50 to 70 per cent of sand	Sandy clay.
(b)	50 to 70 per cent of silt	Silty clay.
(c)	30 to 45 per cent of clay	Heavy clay loam to light clay.
(d)	Over 45 per cent of clay	Clay.

Soil class terms may be qualified if mixed with considerable amounts of gravel, stone, etc. If enough stones over 4½ inches in diameter are present to interfere with cultivation, the term "stony" is prefixed to the soil class. For example, stony clay loam, stony loam, etc. If 30 per cent or more fine, medium or coarse gravel particles up to two inches in diameter are present the term "gravelly" would be prefixed to the soil class; as, gravelly sandy loams, gravelly loams, etc. If a considerable number of small stones or cobbles are present from 2 inches to 4½ inches in diameter the soil is termed "cobbly" rather than "stony."

Peat Soils:

Soils composed predominantly of organic matter are termed "peats." Well decomposed peats are sometimes designated as "mucks" rather than "peats."

(2) WATER RELATIONSHIP OF SOIL TEXTURES:

Soil texture is exceedingly important not only from the standpoint of physical properties and tillage, but primarily from its effect on water relationships. The amount of water that a mineral soil will retain against the pull of gravity depends upon the size of the soil particle. In Table IV the inches of water per foot available to plants that the various soil classes will retain are given. As most agricultural plants will penetrate to a depth of four or more feet, the amount of water a soil will hold to a depth of four feet is fundamentally important. For practical purposes it may be assumed that the amount of water available to plants that the different soil classes will retain under free drainage is as follows:

Sands	¼″ to ½″	per foot.
Sandy loams	1″	per foot.
Fine, sandy loams	1½″ to 1¾″	per foot.
Loams	2″	per foot.
Clay Loams	3″	per foot.
Clays	3½″	per foot.

Thus the range of water retention within a four-foot column of soil varies from one inch to fourteen inches. As a wheat crop will remove about eight inches of water from the soil to produce a twenty-five bushel crop, it is obvious that the lighter textured soils are sub-marginal soils in a region of light precipitation, and also that the heavier textured soils have a drainage problem in regions of high precipitation.

The texture of the parent material also affects the amount of vegetative growth by reason of the differential water capacities. Thus under virgin conditions, different species of plants may be found on different textures and different amounts of organic deposits are produced. On cultivated soils, however, heavier average yields may be expected than from the lighter textured soils.

(3) LIME AND MINERAL RESERVE:

A study of Manitoba soils brings out the importance of the chemical composition of the parent material in relation to soil type. The parent material of a large portion of the soils of Manitoba is composed of lime-stone material. Excessive amounts of lime carbonate affects and modifies the soil forming processes. For example, most of the high-lime soils in the Inter-lake region were formerly covered with forest. Under forest conditions, the water moving downward through the soil leaches the products of weathering so that grey-wooded soils, more or less acid, are developed. In the soils developed on lime-stone material, however, the lime reserve is so high that it prevents leaching processes and prevents the development of an acid condition. Moreover, in the high-lime soils, phosphorus is either low or in a not readily available form, with the result that plants do not thrive as well as on the soils where phosphorus is available. This affects the amount of organic matter which is produced and in Manitoba it is quite apparent that the difference in chemical composition of the soil minerals profoundly affects the soil forming processes. Light textured or sandy soils in the humid region are generally low in potash.

APPENDIX III.

Field Observations of a Soil

Information is often required by farm inspectors, appraisers, land purchasers, and owners, regarding the methods of examining and describing soils on a given property. To supply this information the following is included as an Appendix to this Report.

To make a fairly complete examination of the soils on a given property the observer should proceed as follows:

(1) Ascertain the number of geological deposits or parent materials that occur, such as: boulder till, clay deposits, river overwash, etc. (See Legend, fig. 4).

(2) Note the different topographical positions occurring on each type of parent material: knoll, slope, level and depressed position; or excessively drained, normal or well drained, and poorly drained position. (See fig. 8). The appearance of the vegetation may be used as an indication of special local conditions (re saline areas, etc.).

(3) Select a location typical of each of the parent materials and positions noted in No. (1) and No. (2). An examination of the soil profile at each selected point should be made.

(4) Examine and describe each soil profile, proceeding as follows:

(a) Dig a pit large enough to expose a cross-section through the soil down to the underlying parent material. A spade is essential, a soil auger alone is of little value.

(b) Note the different soil horizons and record:
1, The depth; 2, the color; 3, the texture; 4, the structure; 5, the consistency; 6, intrusions and concretions; and 7, the reaction of each horizon, or sub-horizon. This may be done conveniently on the form on the following page.

1. Depth:

The depth of each soil horizon should be measured and a sketch made on the description sheet.

2. Color:

The color of the original deposits changes under soil forming processes, so that the different horizons will show different colors or combinations of colors. The organic matter, if high, may be black to dark brown. The color may grade from black through grey-black to grey; or from brown through grey-brown to grey. The organic matter in dry upland prairie soils is dark brown (or chocolate) to brown. The organic matter in the more humid prairie soils

SOIL PROFILE DESCRIPTION

Parent Material.................................... Topographical Position.. Location

Horizon	Depth in inches		Color	Texture	Structure	Consistency and Constitution	Intrusions and Concretions	Reaction
"A"		Sketch or Photograph						
"B"								
"C"								

Topography,
Geological deposits,
Drainage,
Stone,
Native vegetation,
Wells and water supply,
Agriculture followed,

Remarks:—

is black to greyish-black. Grey organic matter colors indicate that the soil is either poorly drained, or they may indicate degradation or leaching processes.

Red, yellow, blue and blue-grey colors may arise from the condition of the iron and its combinations. Red or reddish-brown colors indicate that the iron is oxidized and the soil has free drainage and good aeration. Yellow colors may indicate hydrated iron oxides. In sandy soils they frequently indicate a former poorly-drained condition. Mottled red and yellow colors in the sub-soil indicate a fluctuating water table or periodic wet conditions. Blue and blue-grey colors indicate that reduced iron is present and imply poor aeration. Brownish-drab, drab, olive-drab, olive-grey and grey subsoil colors result from the differential oxidation and aeration of clay soils. The more brown the clay is, the better aerated and better drained the soil is. The more grey the clay is, the less well drained or aerated the soil is.

White and greyish-white coloration may be imparted to the soil by specks of lime carbonate, gypsum, soluble salts, silica grains, and some organic compounds. Concretions may be present, giving marbling or spotted patterns. These should be noted under concretions.

Structural soil aggregates may show one color inside the aggregates and a different colored coating on the outside. This denotes the movement into the horizon of material from above. A glossy coating on the outside of the aggregates implies that concentration or precipitation is taking place. A dull appearance on the outside of the aggregates implies that removal of material from the horizon by leaching is taking place.

The color of the parent material below the soil will depend upon the kind of the geological deposit and its degree of oxidation (or aeration).

The color of the soil will vary to a marked degree, depending upon the moisture content, the amount of light, and the degree of sunlight. A soil that is wet or that is examined on a dull day, may show a marked difference in color to the colors which may be observed when the soil is dry, or that are noted when examined in bright sunlight.

3. *Texture:*

(See Appendix II).

4. *Structure:*

Structure refers to the arrangement of the soil particles into aggregates. The following are the common structures observed:

(a) *Structureless or Single Grained:* The lack of structure implies a low content of colloidal and clay particles, and a low content of organic matter.

(b) *Granular:* The soil may be formed into aggregates more or less crumb-shaped and varying in size from pulverescent, finely granular, granular and coarsely granular. This type of structure is common in grassland soils. It is characteristic of black earth soils and is responsible for the mellow, friable consistency of the good prairie soils.

(c) *Nut-Like:* The aggregates may be from pea-size to large, nut-like aggregates and may be described as finely nutty, nutty, coarsely nutty. This type of structure is characteristic of the "B" horizon of wooded soils.

(d) *Fragmental:* If the aggregates are of similar size to the granular or nutty, but angular or with more or less sharp corners, rather than rounded, they are described as fragmental. Soil horizons in which the structural aggregates are fragmental are generally high in clay and low in organic matter.

(e) *Cloddy:* A cloddy structure implies larger aggregates than nut structure, but they may be small, medium or large clods.

(f) *Prismatic:* Prismatic structures are structural aggregates arranged in columns. They are often six-sided, with the angles fairly well defined, the tops of the prisms are generally flat. They may be described as small, medium or large prismatic aggregates. This type of structure is characteristic of the "B_1" horizon of alkalinized soils.

(g) *Columnar:* Columnar structure is arranged in columns, often irregular and without distinct corners. The tops of the columns are generally rounded. They may be described as small, medium or large columnar or column-like aggregates. Round narrow columns are characteristic of the structure in dry steppe soils, and coarse, round-topped columnar structure is characteristic of the "B_1" horizon of degraded alkalinized soils.

(h) *Platy:* Platy structural aggregates are wider than they are deep. Harsh platy structures are characteristic of the "A_2" horizon of well-developed, grey-wooded and podzol soils. Diagonally platy aggregates are characteristic of the "A_2" horizon of alkalinized soils which are undergoing degradation.

(i) *Massive:* When the soil is in a cohesive mass and more or less amorphous the structure is termed massive. (See fig. 55).

5. Consistency and Constitution:

Consistency refers to the manifestation of cohesion, plasticity and friability.

Constitution refers to the manifestation of porosity or compactness of a soil.

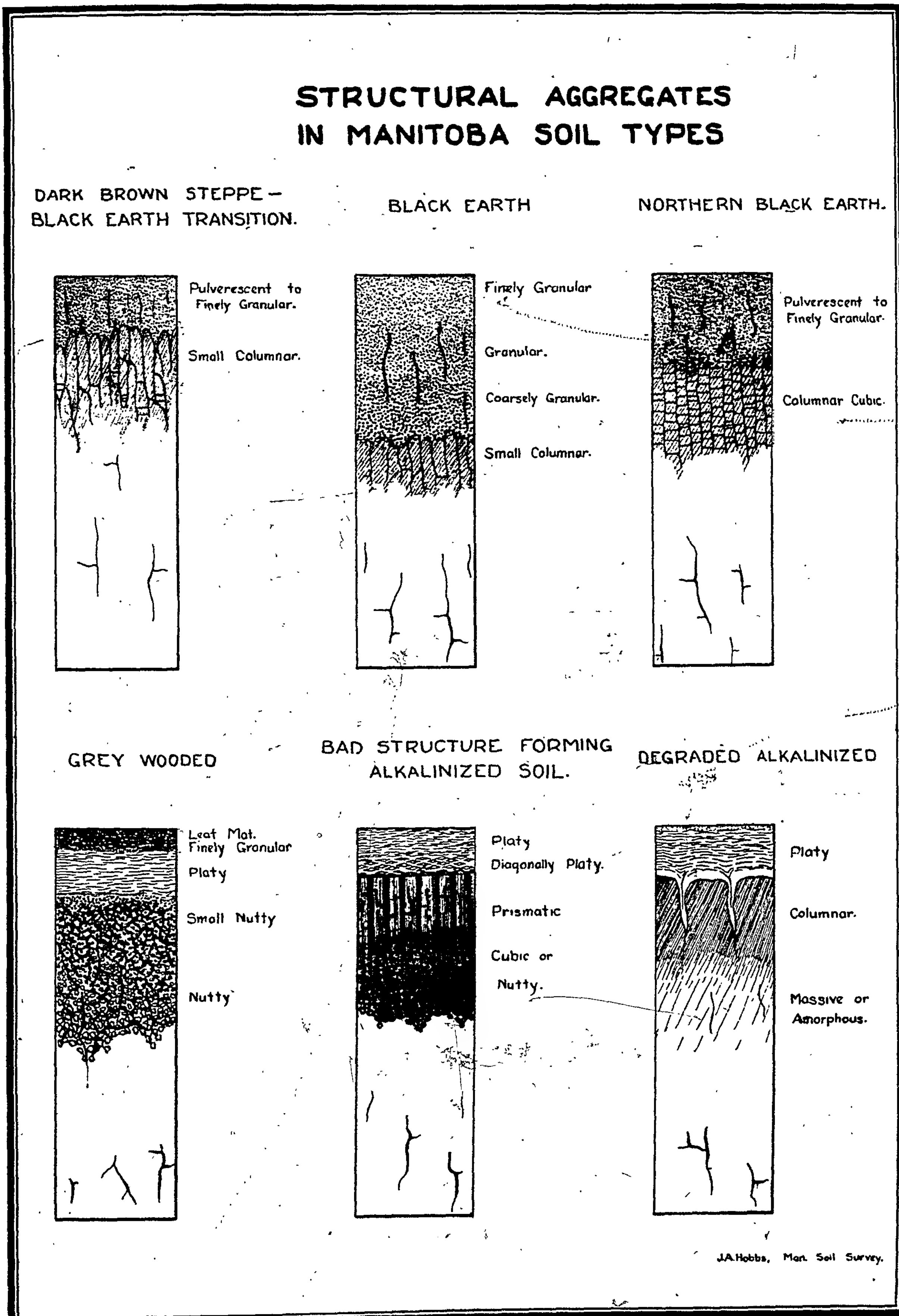


FIGURE 55
Structural aggregates in Manitoba soil types.

TERMS USED:

Loose, soft, stiff, tight, tough, tenacious, firm, hard, brittle; cheesy, plastic, sticky; crumbly, friable, mellow; compact, cemented, indurated; impervious, dense, porous, spongy, cellular, tubular.

6. Intrusions and Concretions:

Intrusions may result from the cracking and the filling-in, or infiltration of material into the fissures, or to the material carried into one horizon from another by burrowing animals.

Concretions refer to the chemical products of weathering which have accumulated in the pores or cavities or between the soil grains and aggregates, such as soluble salts, lime carbonate, gypsum, iron concretions, etc. The kind of concretions and their location indicate the chemical processes which produced them.

7. Reaction:

The reaction of a soil, whether acid, neutral or alkaline, may be determined by using brom-thymol blue as an indicator. This indicator turns blue if the soil is alkaline, green if it is neutral, and yellow if it is acid.

APPENDIX IV.

Altitude of Lake Agassiz Beaches in Manitoba According to Warren Upham*

Beaches		Feet Above Sea Level: On the International Boundary	Feet Above Sea Level: On the Latitude of Gladstone, Arden and Neepawa, Manitoba
Herman Beaches	a	1230	....
	aa	1222	....
	b	1212	1315
	bb	1205	1295
	c	1190	1275
	d	1180	1255
	dd	1175	1245
Norcross Beaches	a	1145	1215
	b	1130	1185
Tintah Beaches	a	1105	1150
	b	1080	1120
Campbell Beaches	a	1045	1080
	aa	1035	1070
	b	1022	1055
McCauleyville Beaches	a	1007	1035
	aa	998	1023
	b	990	1012
Blanchard Beaches	a	975	995
	b	960	980
	c	947	965
Hillsboro Beach		935	953
Emerado Beach		902	920
Ojata Beach		877	895
Gladstone Beach		857	875
Burnside Beach		837	855
Ossowa Beach		822	840
Stonewall Beach		805	820
Niverville Beach		....	775

*Warren Upham: "Glacial Lake Agassiz in Manitoba." P. 92 E, Geological and Natural History Survey of Canada, 1890.

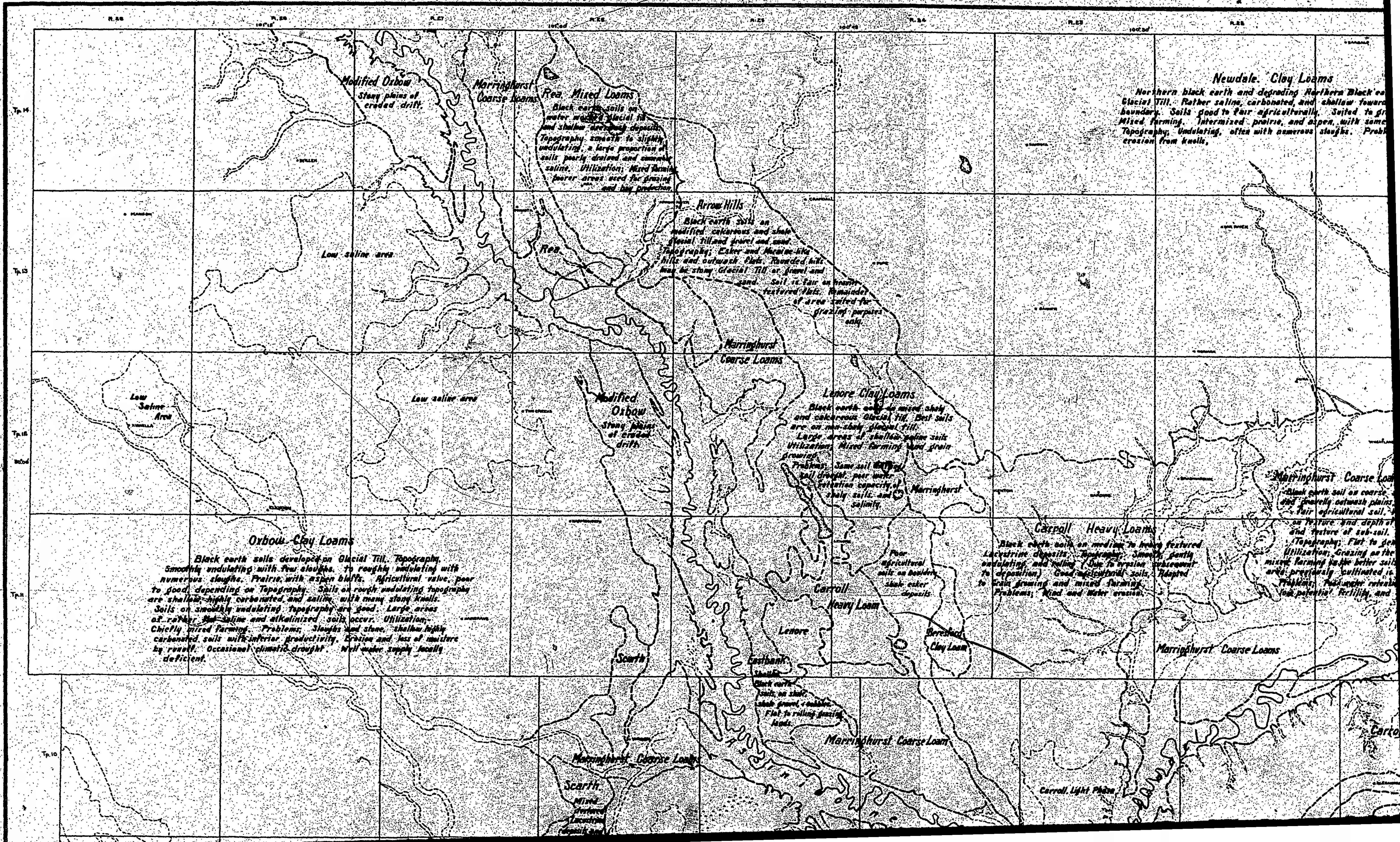
1 of

SHEET 4

LAND CLASSIFICATION MAP

VIRDEN AREA IN MANITOBA

Scale—One Inch Equals Three Miles

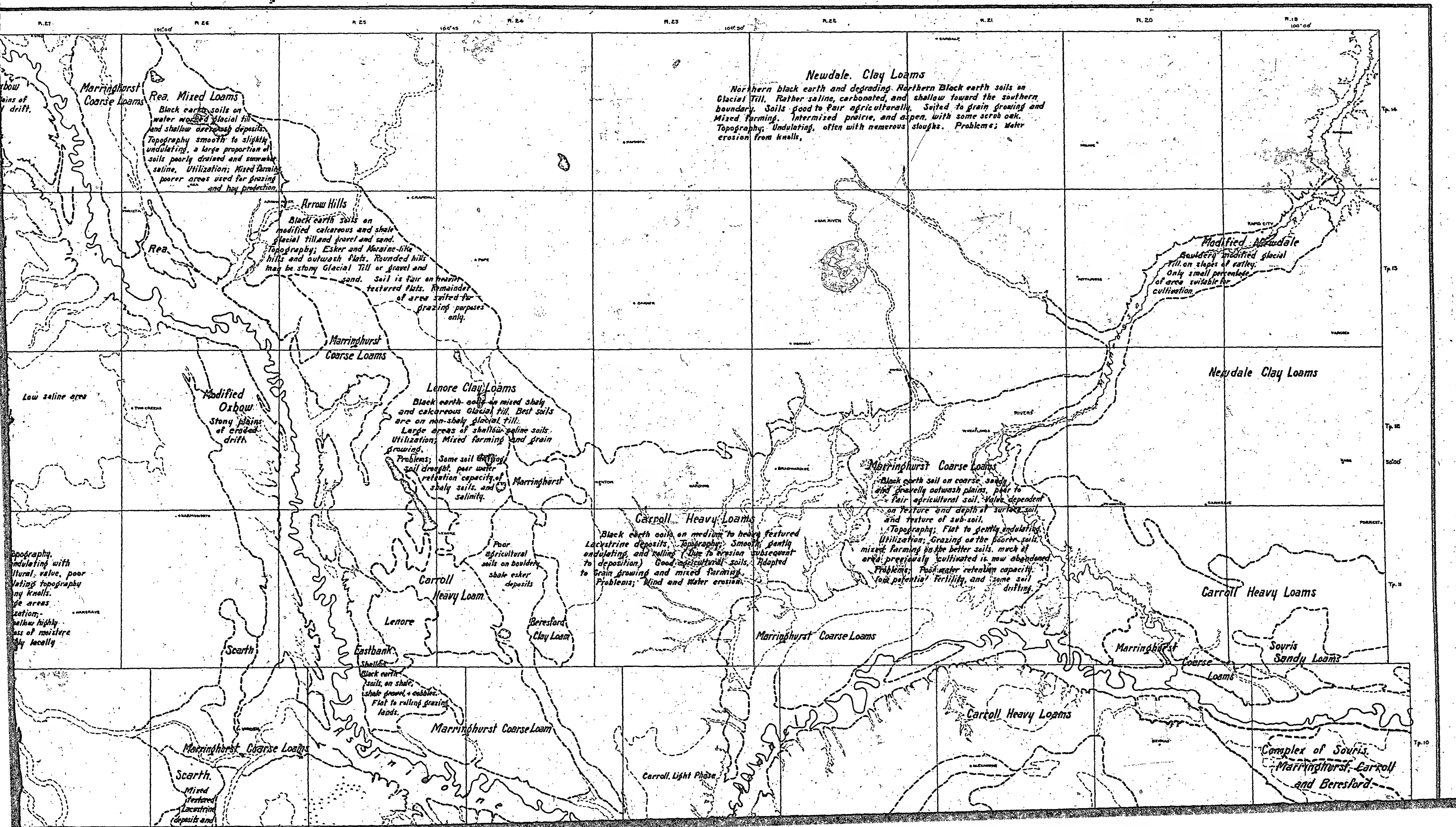


LAND CLASSIFICATION MAP

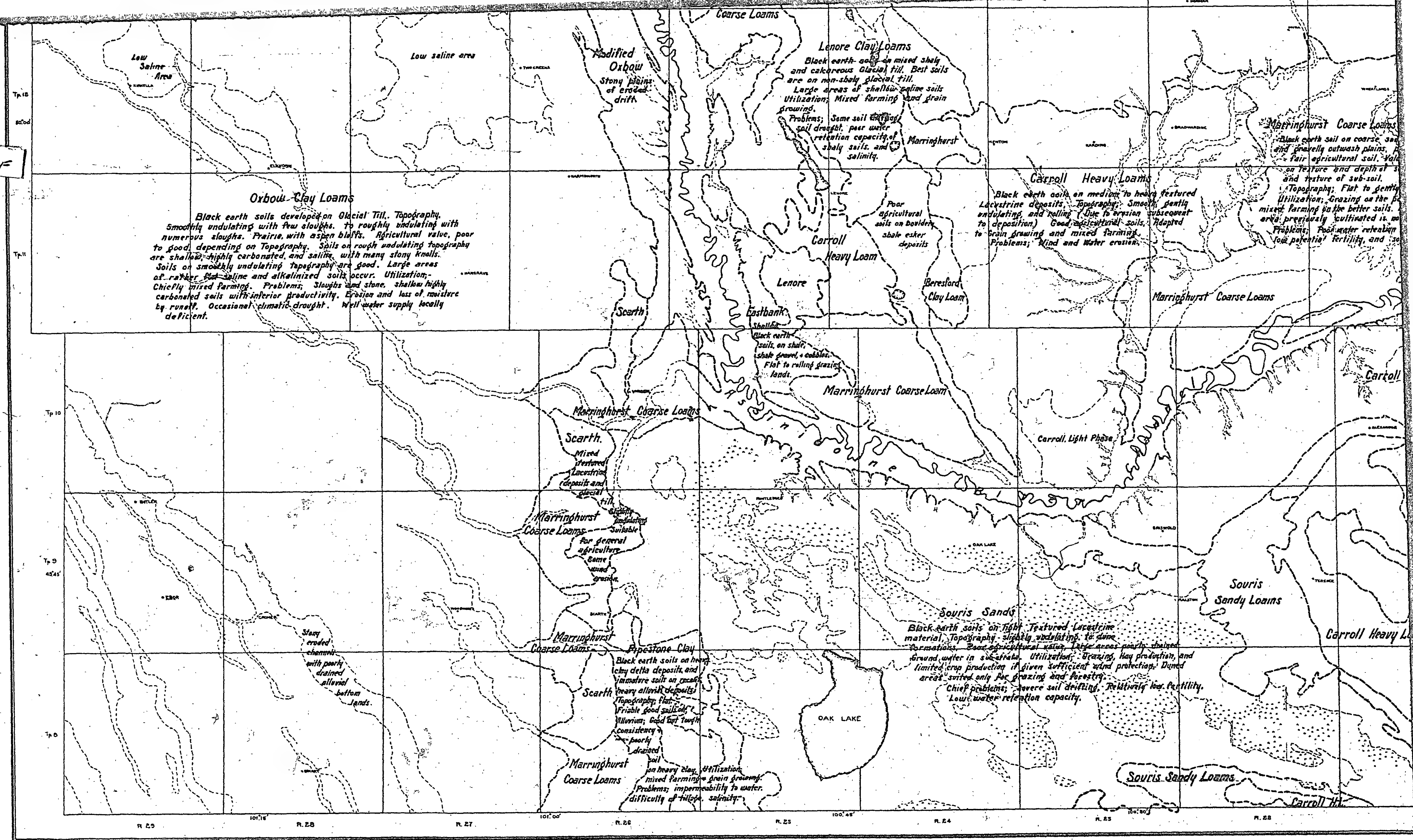
2 of

VIRDEN AREA IN MANITOBA

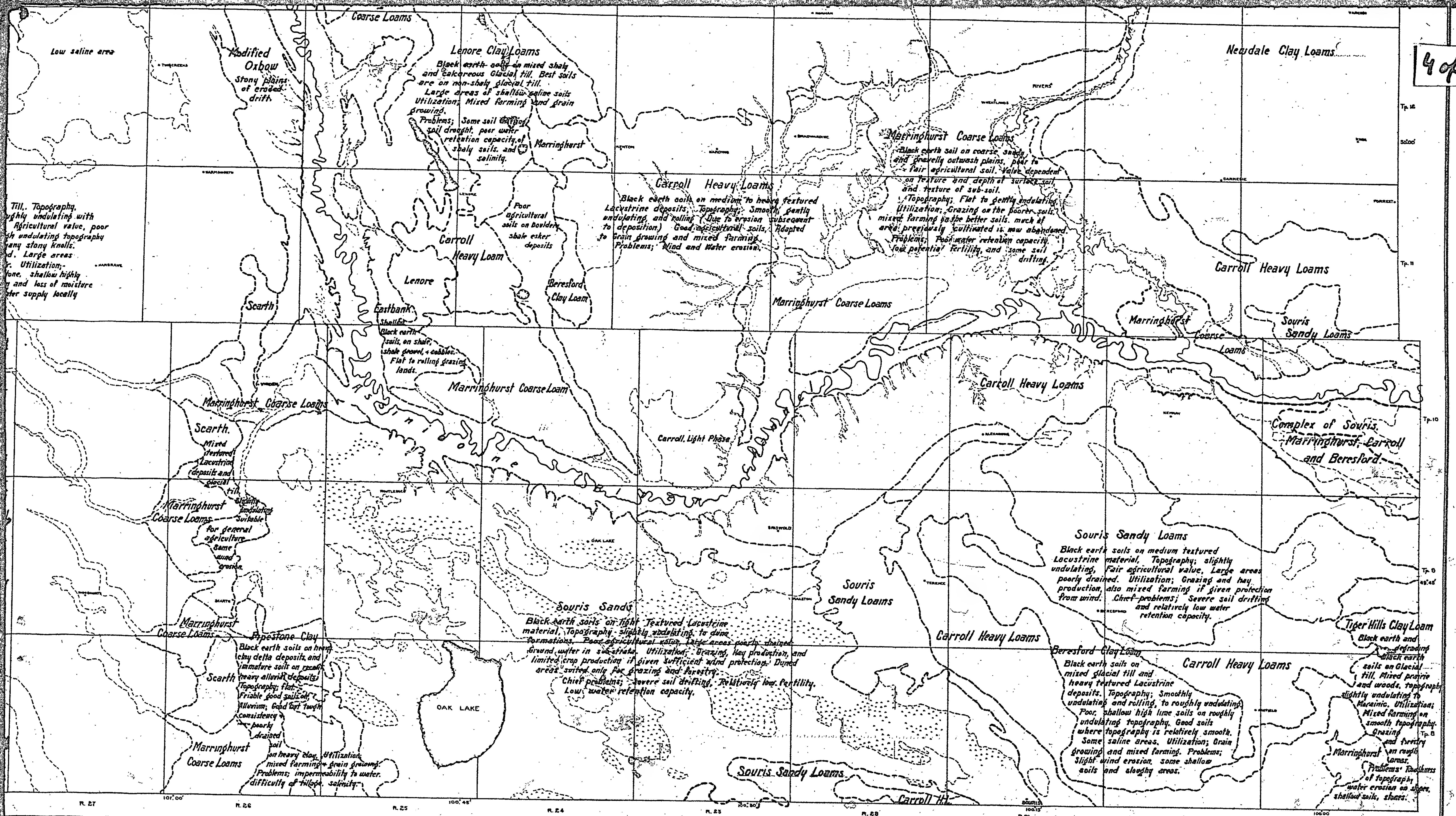
Scale—One Inch Equals Three Miles



3 OF



The names of the soil associations shown in the generalized lan
fication sheet are local place names given to the respective soil asso
Each name was selected, either from the place where the soil type
established, or from some place within the area containing the soi
designated.



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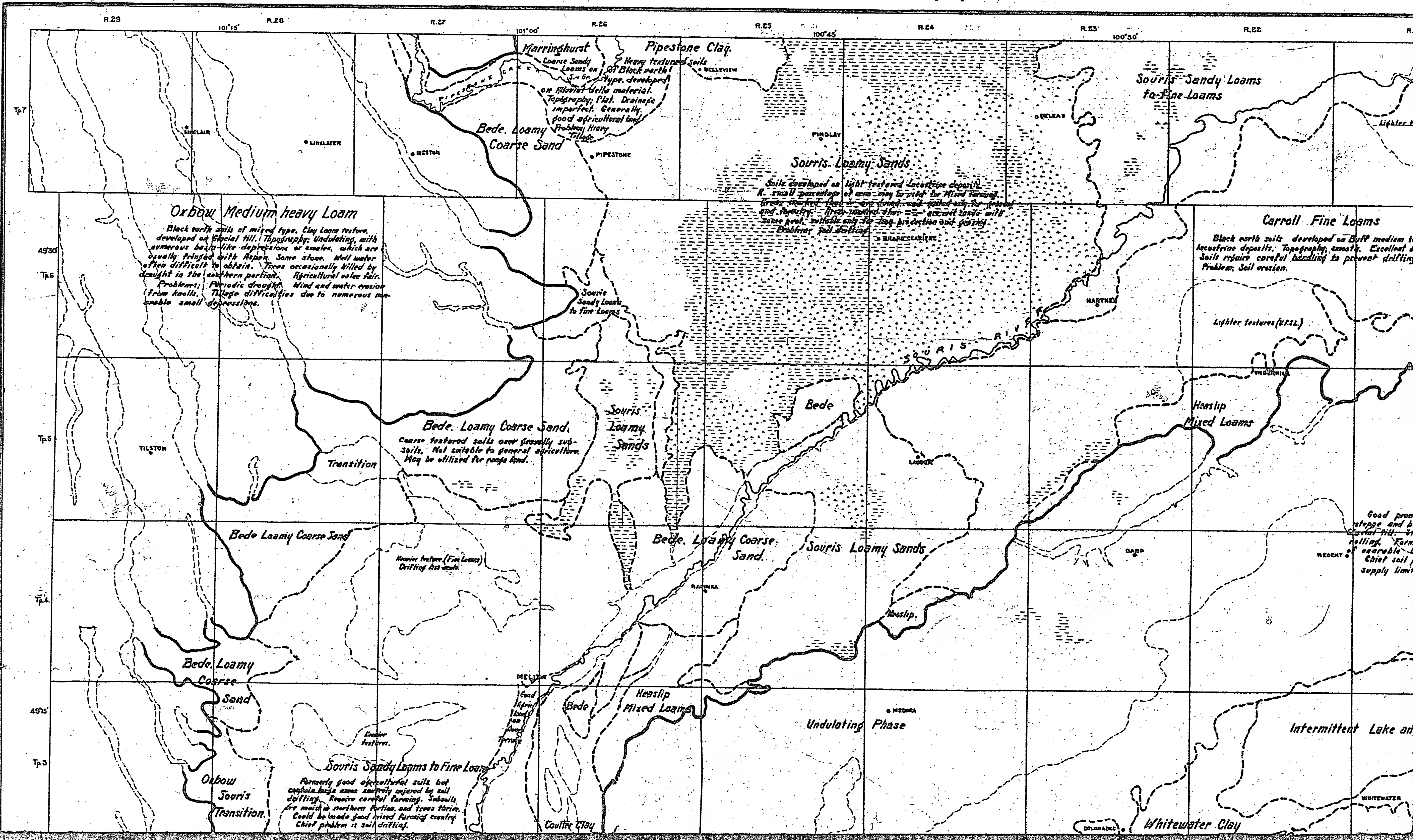
1 of 1

SHEET 1

LAND CLASSIFICATION MAP

SOUTH-WESTERN MANITOBA

Scale—One Inch Equals Three Miles

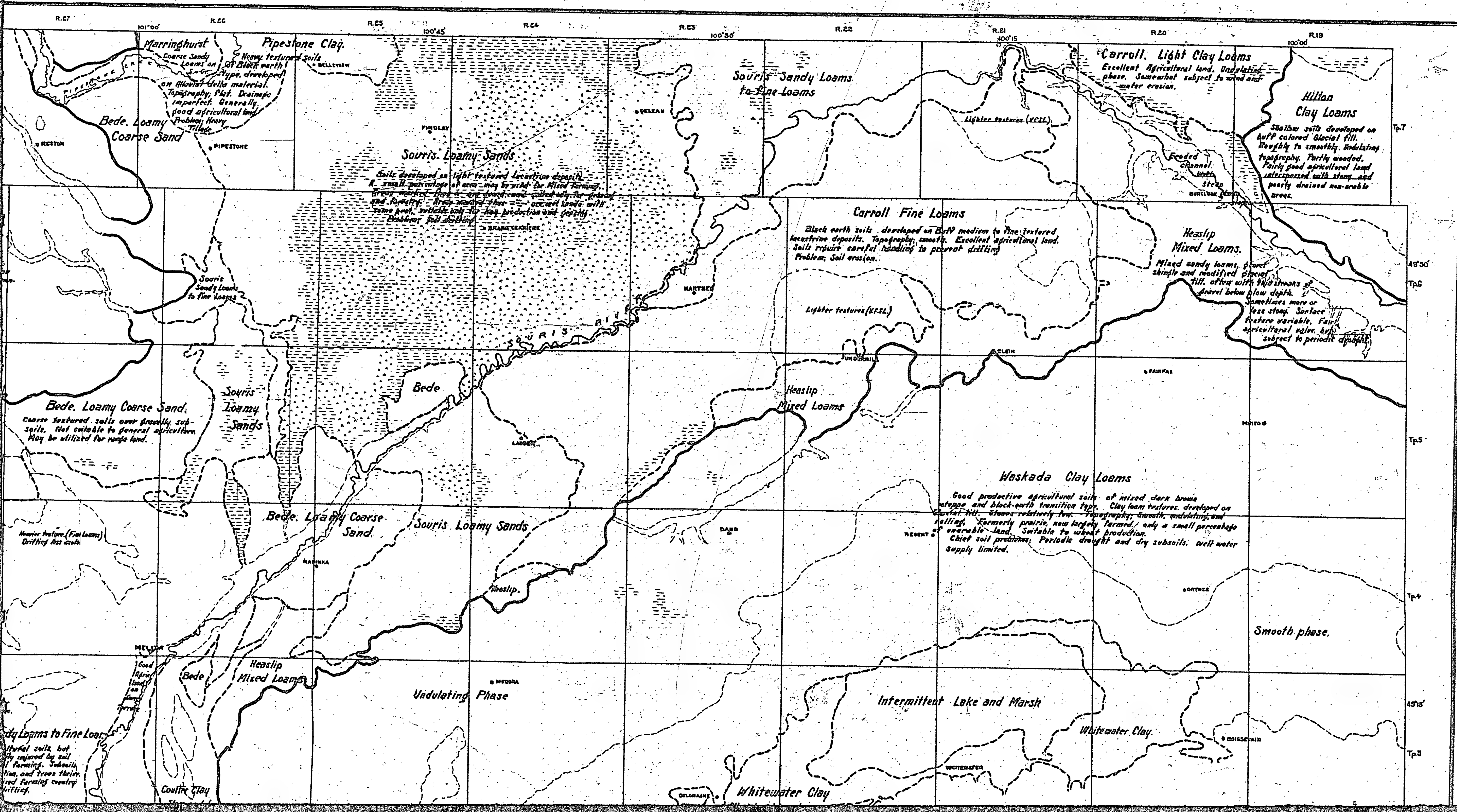


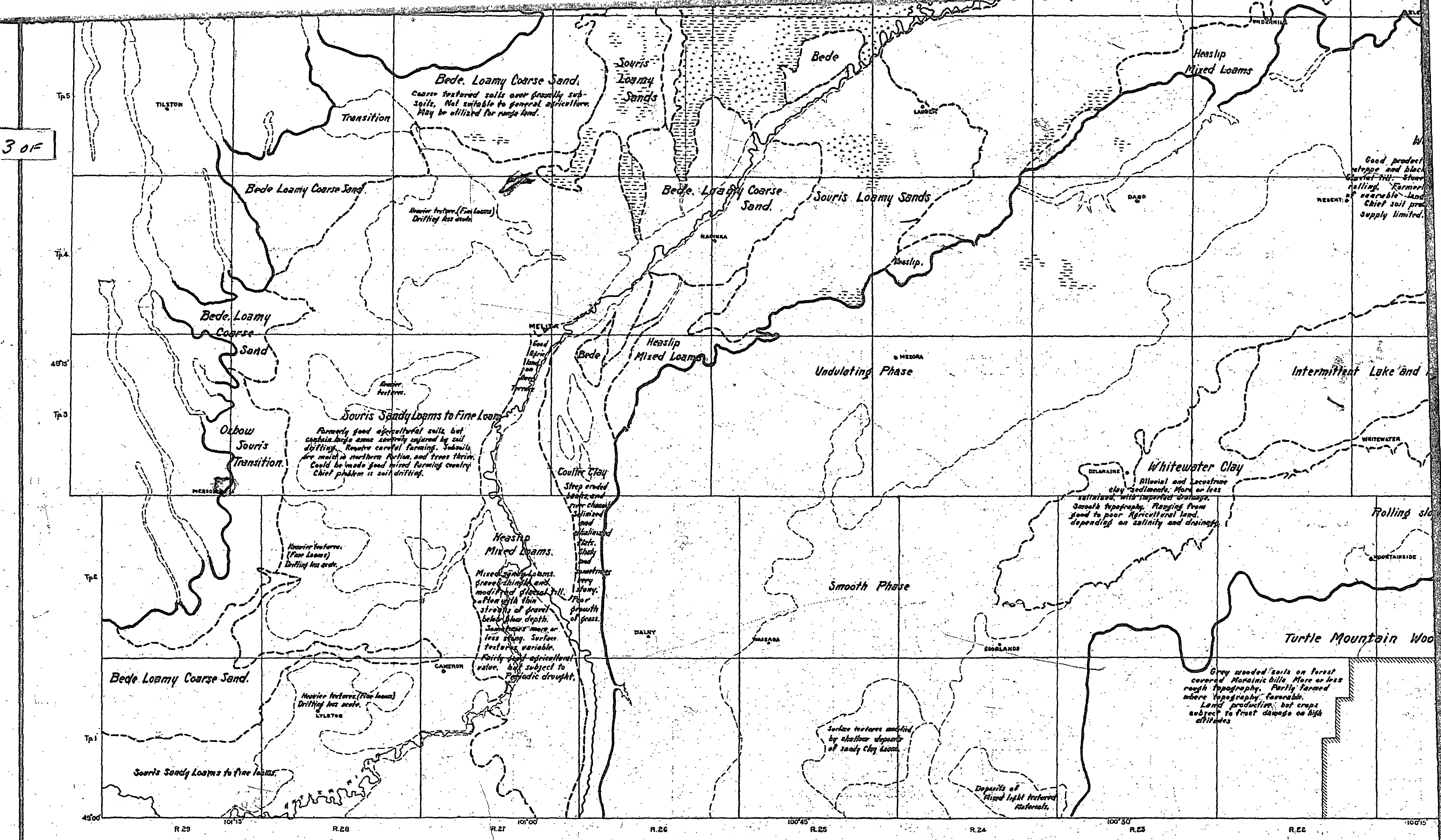
LAND CLASSIFICATION MAP

2 OF

SOUTH-WESTERN MANITOBA

Scale—One Inch Equals Three Miles





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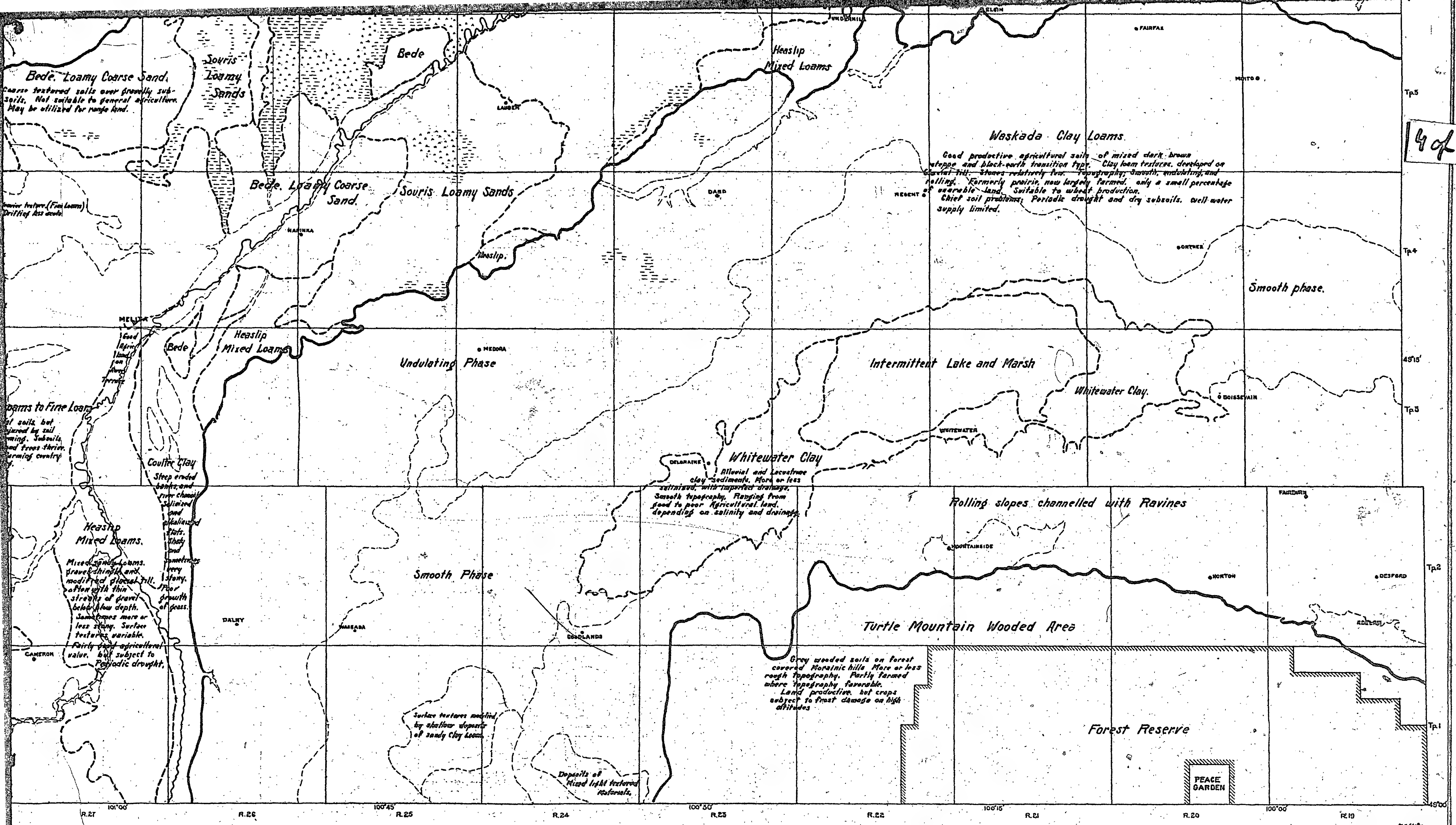

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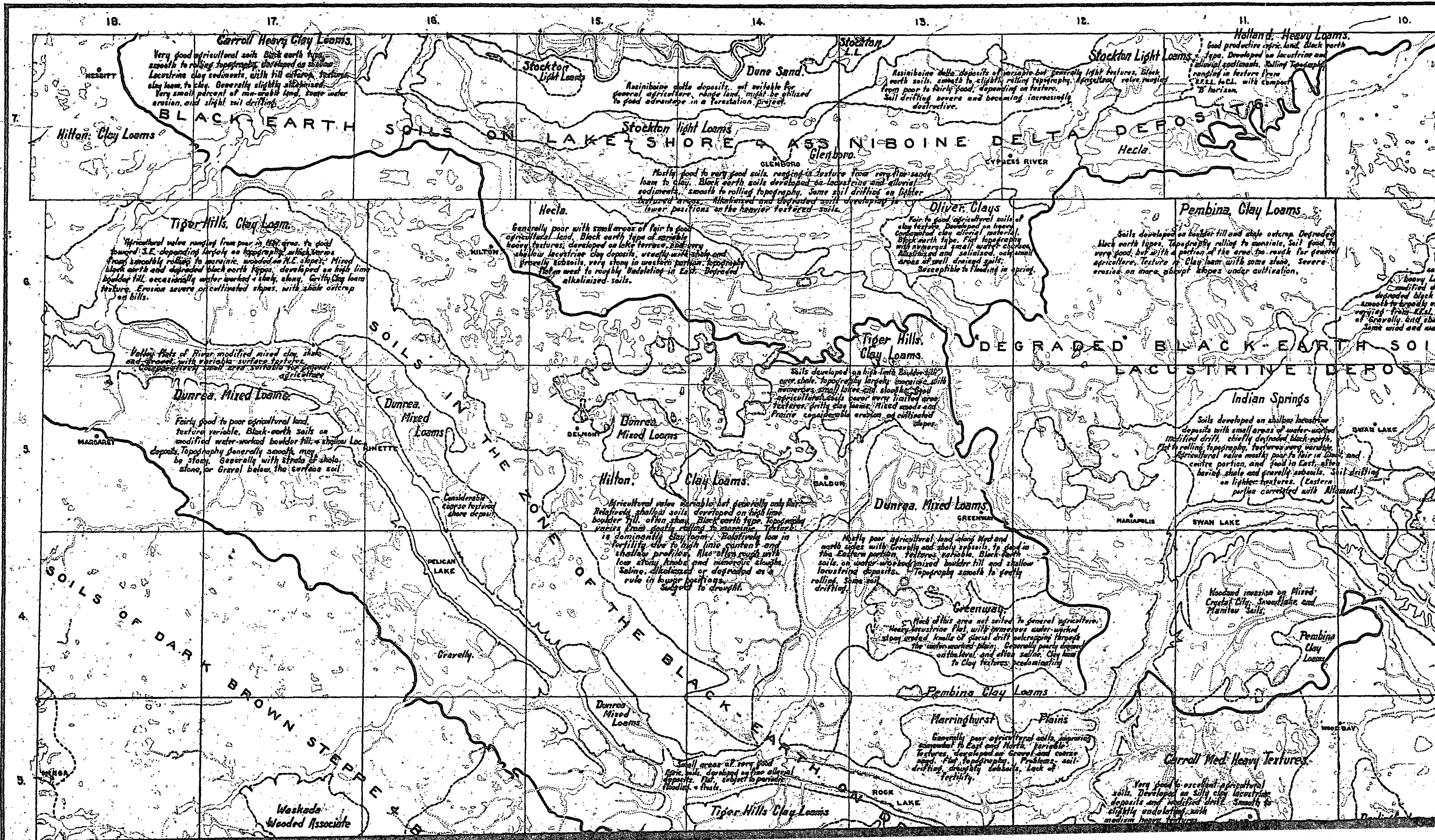
1 of 1

LAND CLASSIFICATION MA

SOUTH-CENTRAL MANITOBA

Scale—One Inch Equals Three Miles

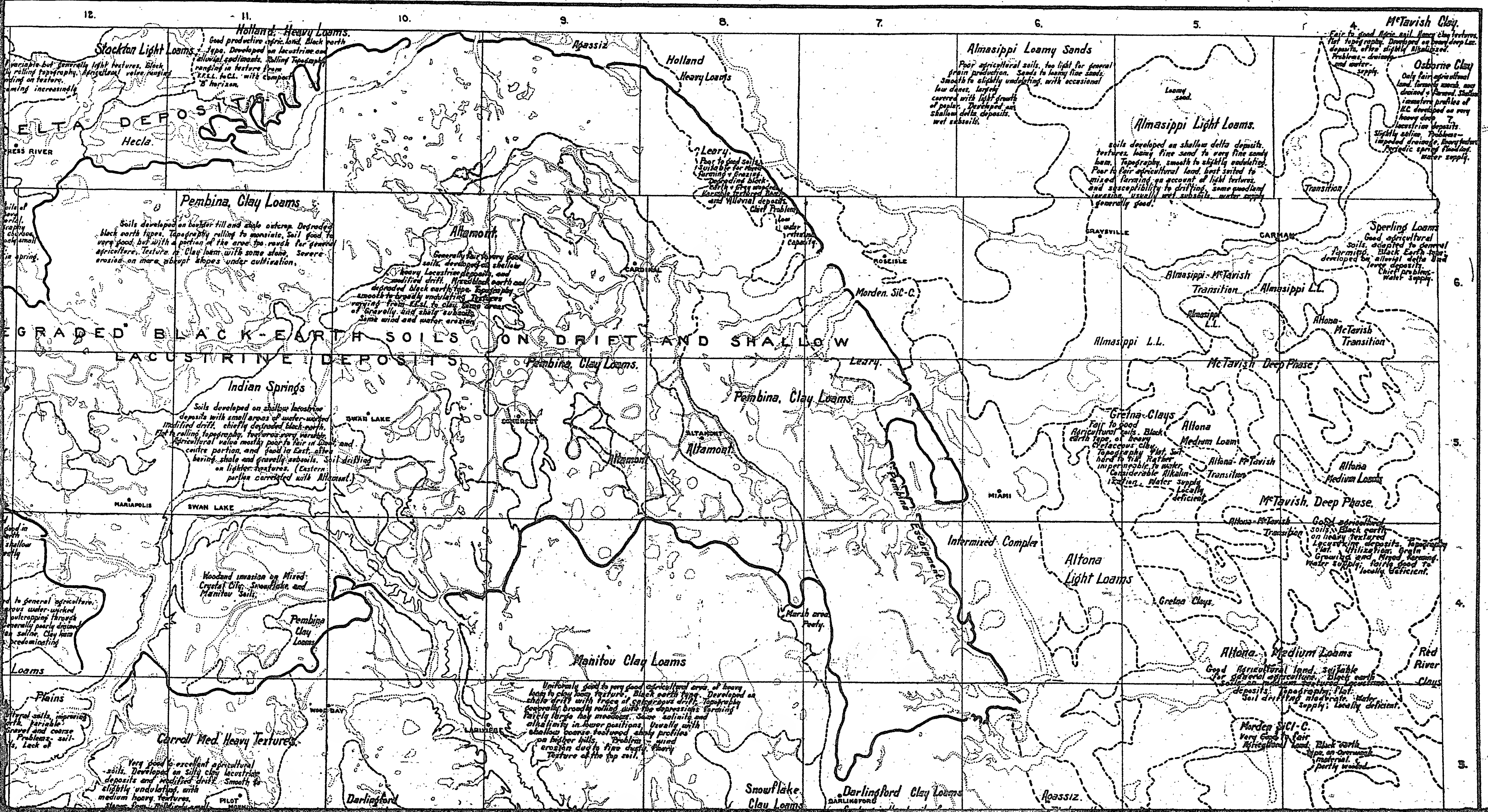
SHEET 2

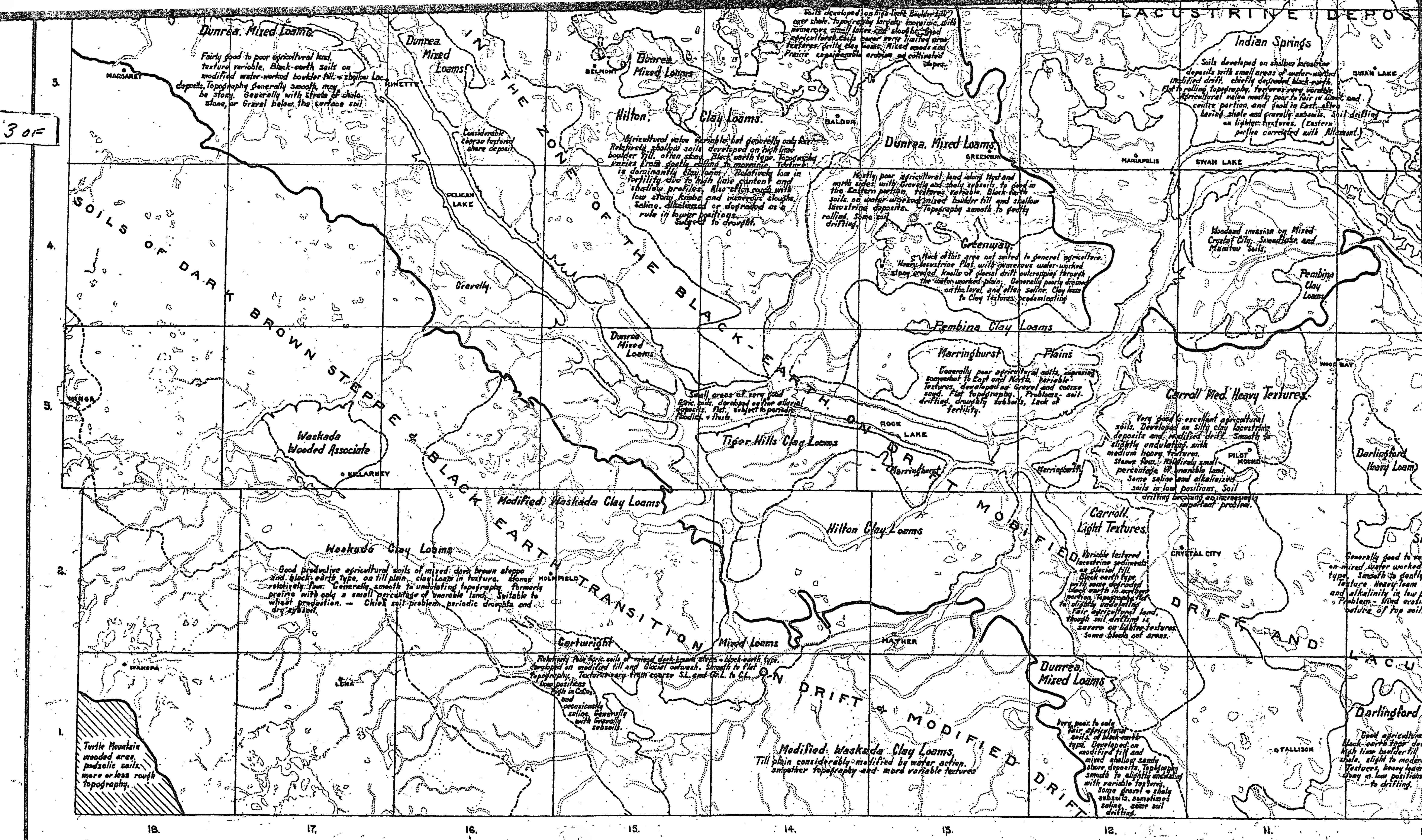


LAND CLASSIFICATION MAP

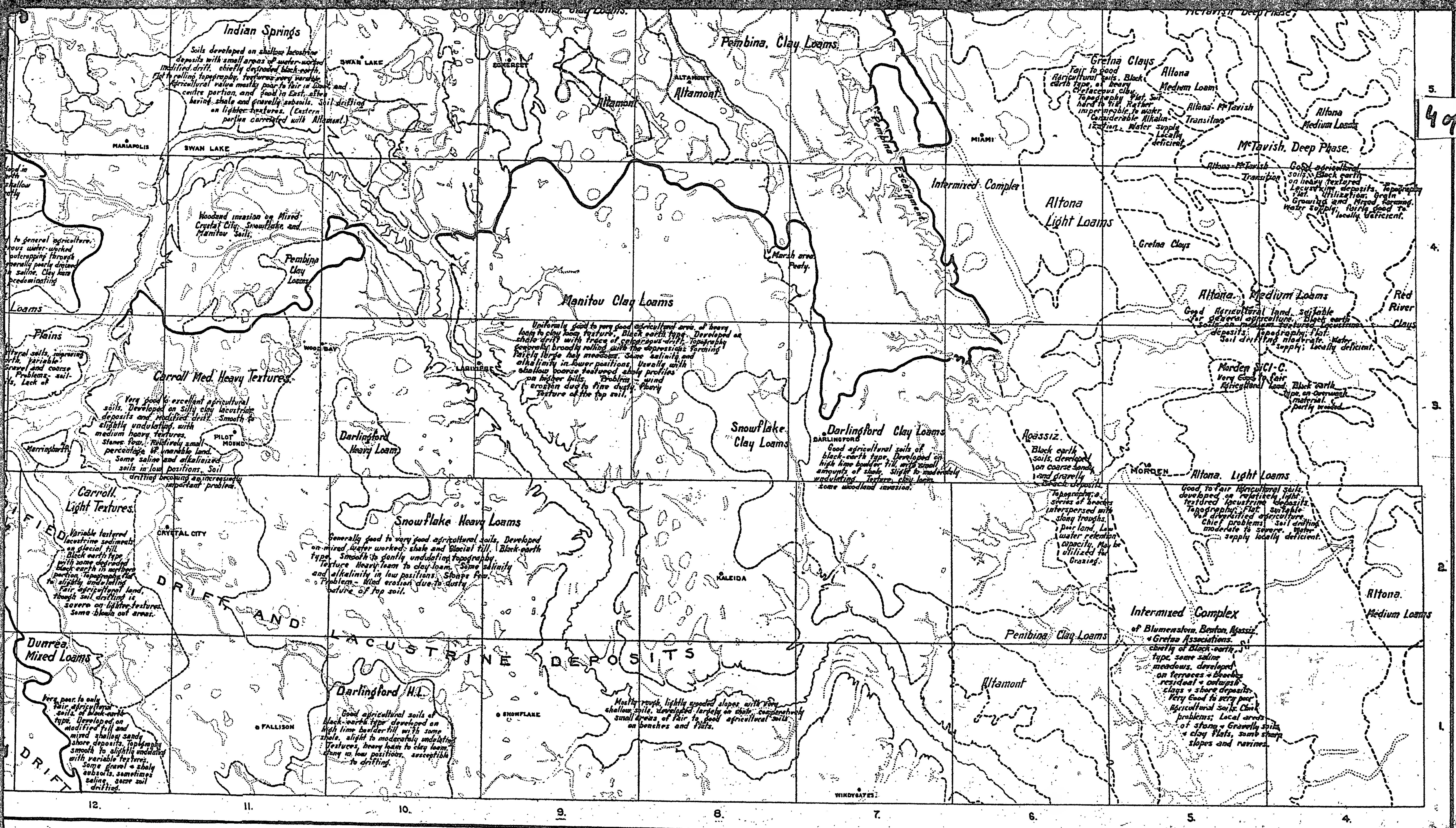
SOUTH-CENTRAL MANITOBA

Scale—One Inch Equals Three Miles





3 of
LACUSTRINE DEPOS
Dunrea. Mixed Loams.
Fairly good to poor agricultural land, texture variable. Black-earth soils on modified water-worked boulder till & shallow Lac. deposits. Topography generally smooth, may be stony. Generally with strata of shale, stone, or Gravel below the surface soil.
MARGARET
NINETTE
Dunrea. Mixed Loams
IN THE ZONE OF THE BLACK-EARTH ON DRIFT MODIFIED DRIFT AND LACU
BELMONT
Dunrea. Mixed Loams
Hilton.
Clay Loams.
BALDUR
Considerable coarse textured shore deposits
Dunrea. Mixed Loams.
GREENWAY
Indian Springs
SWAN LAKE
MARIAPOLIS
SOILS OF DARK BROWN STEPPE & BLACK EARTH TRANSITION ON DRIFT & MODIFIED DRIFT
PELICAN LAKE
Greenway.
Woodland invasion on Mixed Crystal City, Snowflake and Manitou Soils.
Pembina Clay Loams
Gravelly.
Pembina Clay Loams
Dunrea Mixed Loams
Marringhurst Plains
Carroll Med. Heavy Textures.
Waskada Wooded Associate
KILLARNEY
Tiger Hills Clay Loams
ROCK LAKE
Marringhurst
PILOT MOUND
Darlingford Heavy Loam
Modified Waskada Clay Loams
Carroll Light Textures.
Hilton Clay Loams
CRYSTAL CITY
Waskada Clay Loams
Good productive agricultural soils of mixed dark brown steppe and black-earth type, on till plain, clay Loams in texture, stones relatively few. Generally smooth to undulating topography, formerly prairie with only a small percentage of unarable land. Suitable to wheat production. — Chief soil problem periodic droughts and dry subsoil.
HOLMFIELD
Cartwright
Mixed Loams
MATHER
WAKOPA
LENA
Dunrea. Mixed Loams
Darlingford
Turtle Mountain wooded area, podzolic soils, more or less rough topography.
Modified Waskada Clay Loams,
Till plain considerably modified by water action, smoother topography and more variable textures
TALLISON
18.
17.
16.
15.
14.
13.
12.
11.
10
5.
4.
3.
2.
1.



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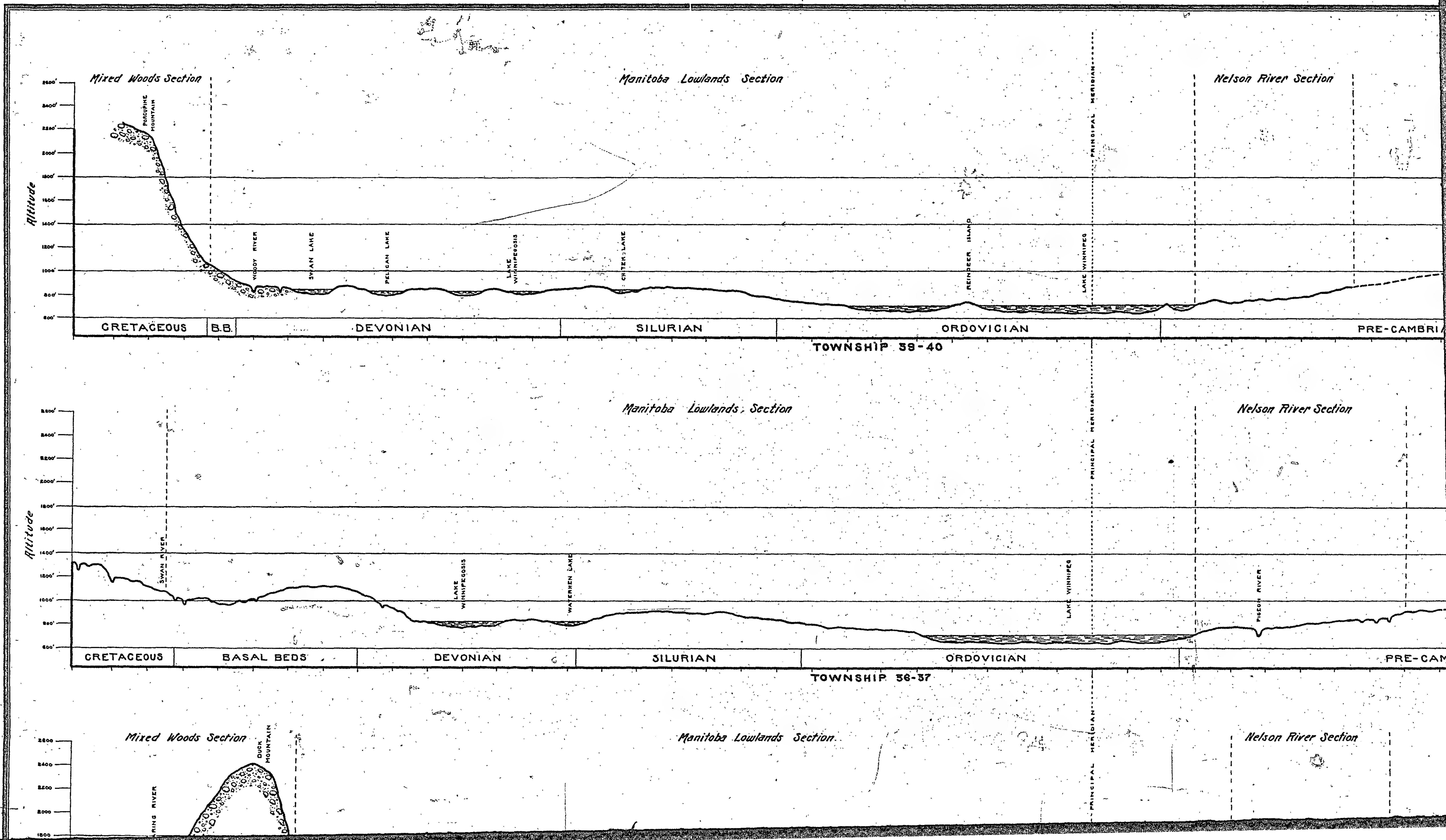
1 of 1

FIGURE 6

GENERALIZED CROSS-SECTIONS OF MANITOBA

SHOWING

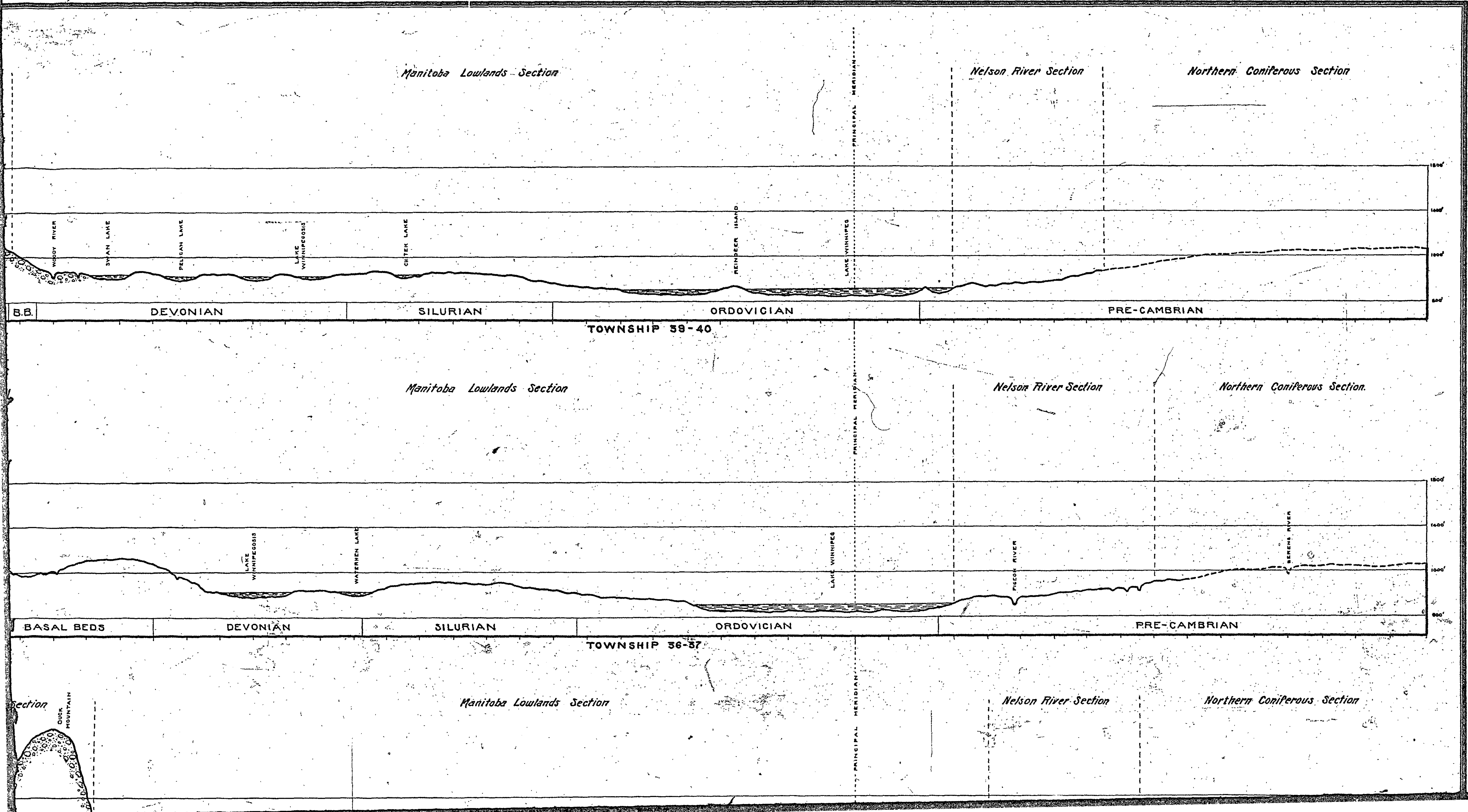
SLOPE, ALTITUDES, VEGETATIVE ZONES, SURFACE GEOLOGICAL DEPOSITS, AND UNDERLYING ROCKS



GENERALIZED CROSS-SECTIONS OF MANITOBA

SHOWING

SLOPE, ALTITUDES, VEGETATIVE ZONES, SURFACE GEOLOGICAL DEPOSITS, AND UNDERLYING ROCKS



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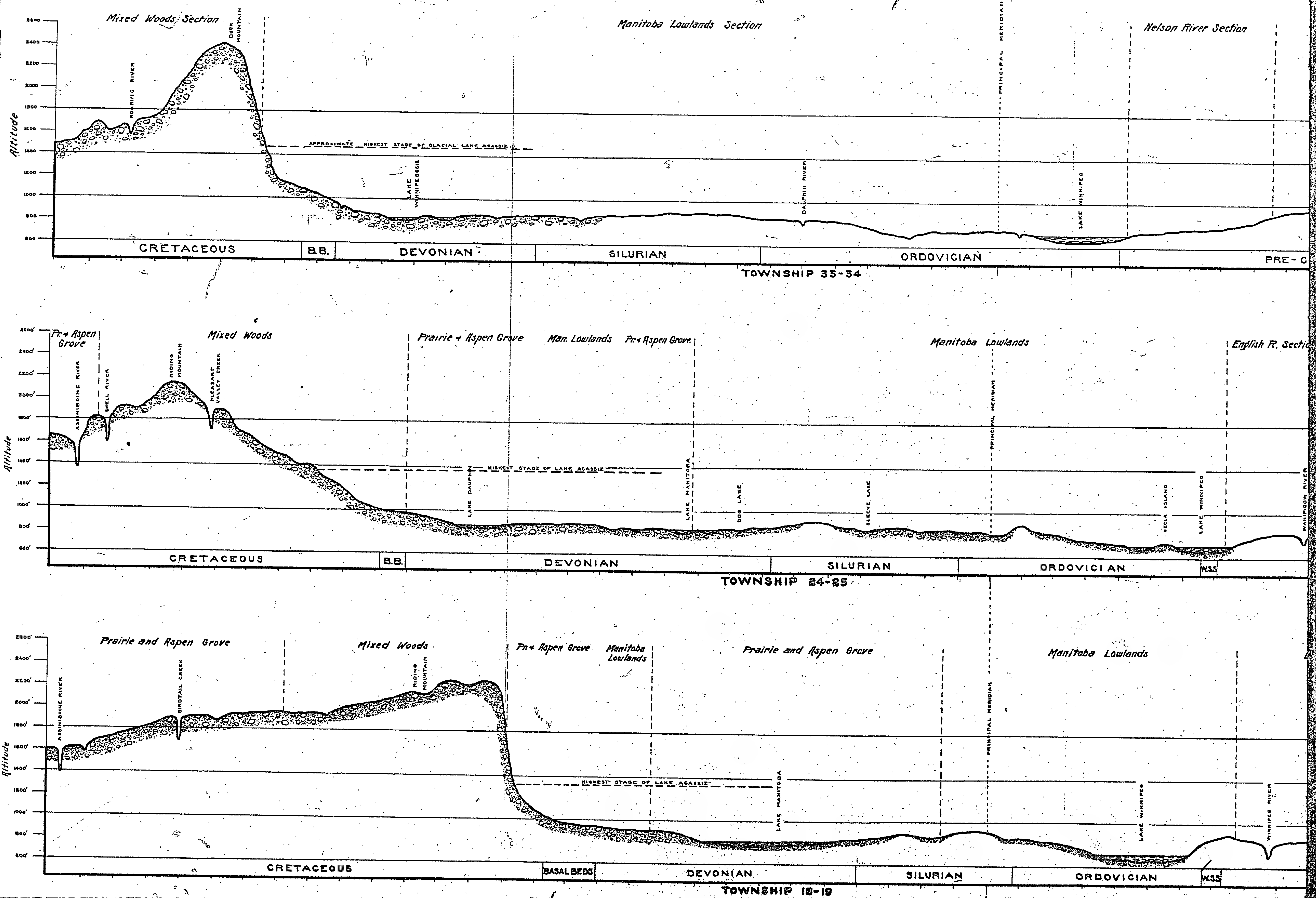
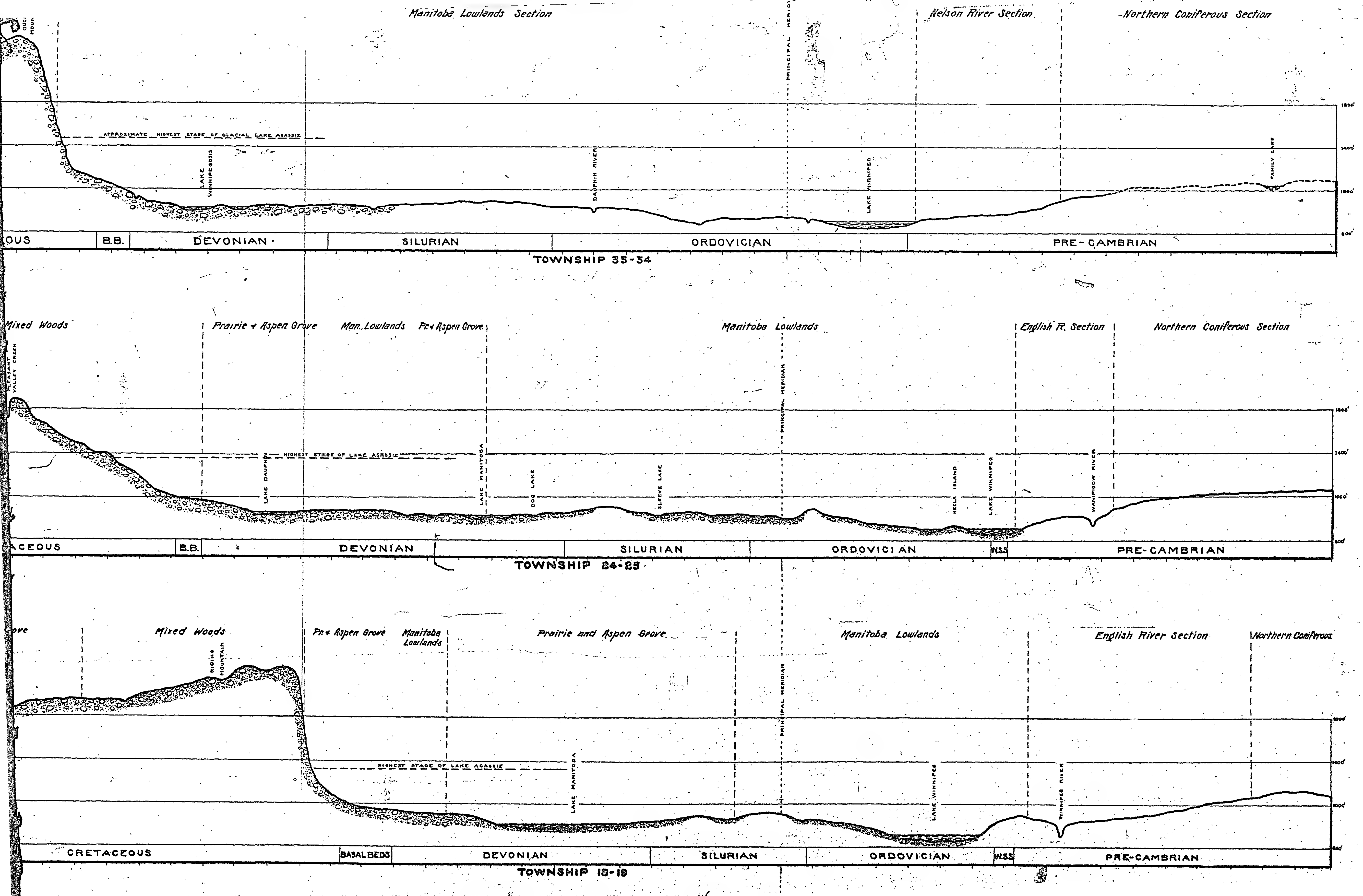


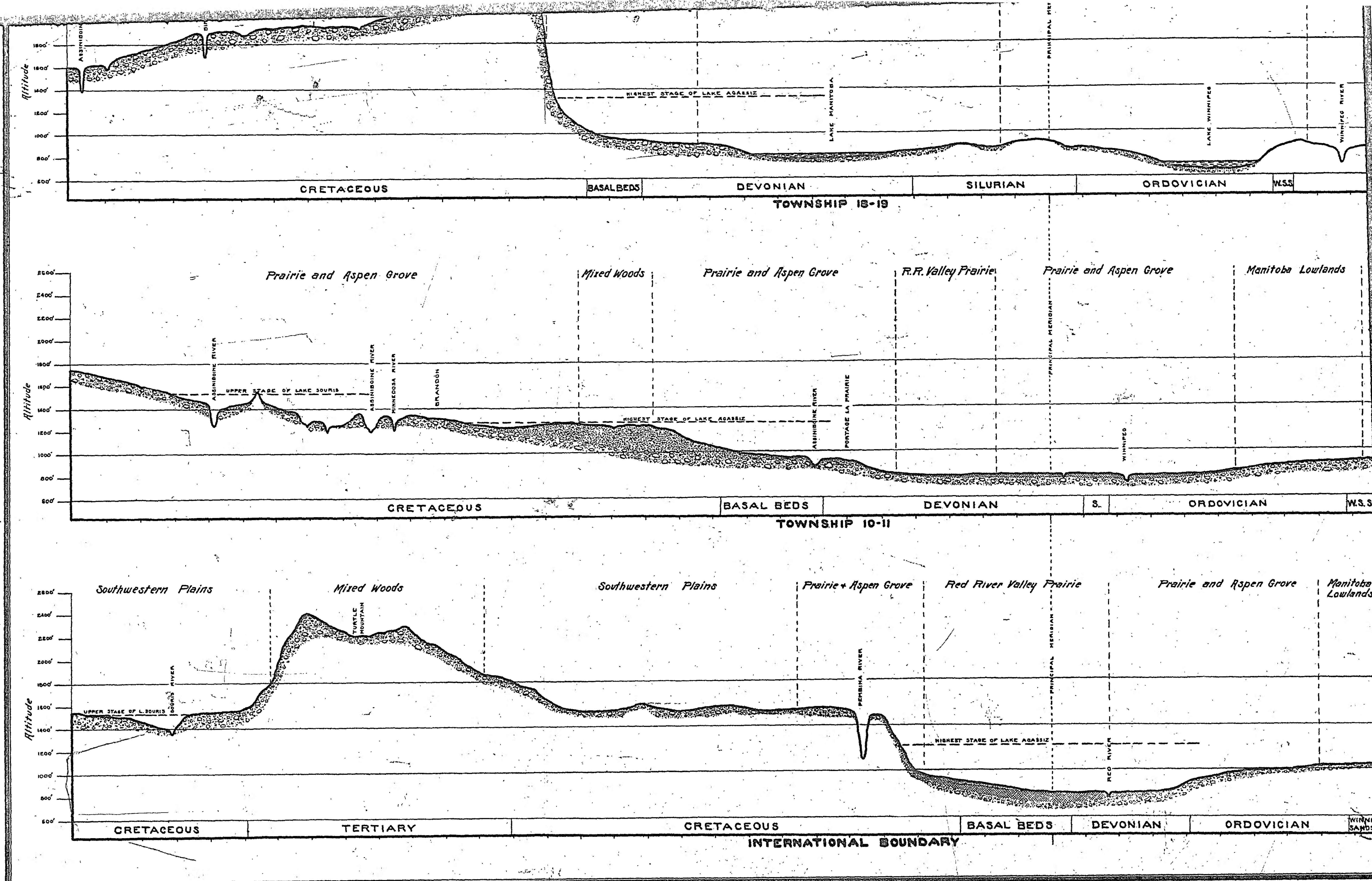
Mixed Woods Section
Manitoba Lowlands Section
Nelson River Section
Altitude
Duck Mountain
Roaring River
Approximate highest stage of glacial Lake Agassiz
Lake Winnipegosis
Dauphin River
Principal Meridian
Lake Winnipeg
CRETACEOUS
B.B.
DEVONIAN
SILURIAN
ORDOVICIAN
PRE-C
TOWNSHIP 33-34
Pr.+ Aspen Grove
Mixed Woods
Prairie + Aspen Grove
Man. Lowlands
Pr.+ Aspen Grove
Manitoba Lowlands
English R. Sectio
Assiniboine River
Shell River
Riding Mountain
Pleasant Valley Creek
Highest stage of Lake Agassiz
Lake Dauphin
Lake Manitoba
Dog Lake
Sleeve Lake
Principal Meridian
Hecla Island
Lake Winnipeg
Wanipigow River
CRETACEOUS
B.B.
DEVONIAN
SILURIAN
ORDOVICIAN
W.S.S.
TOWNSHIP 24-25
Prairie and Aspen Grove
Mixed Woods
Pr.+ Aspen Grove
Manitoba Lowlands
Prairie and Aspen Grove
Manitoba Lowlands
Assiniboine River
Birdtail Creek
Riding Mountain
Highest stage of Lake Agassiz
Lake Manitoba
Principal Meridian
Lake Winnipeg
Winnipeg River
CRETACEOUS
BASAL BEDS
DEVONIAN
SILURIAN
ORDOVICIAN
W.S.S.
TOWNSHIP 18-19

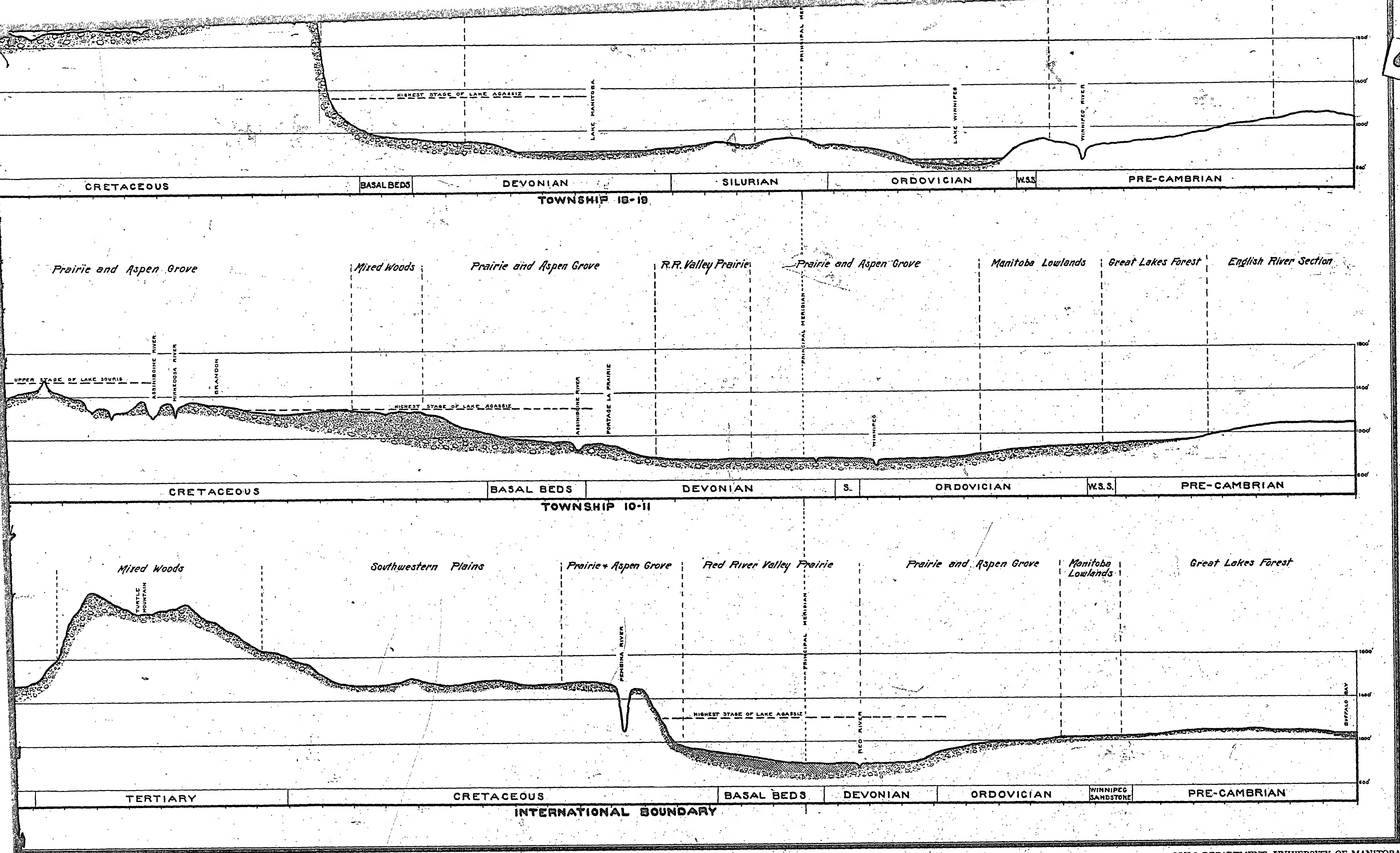


Manitoba Lowlands Section
Nelson River Section
Northern Coniferous Section
APPROXIMATE HIGHEST STAGE OF GLACIAL LAKE AGASSIZ
LAKE WINNIPEGOSIS
DAUPHIN RIVER
PRINCIPAL MERIDIAN
LAKE WINNIPEG
FAMILY LAKE
1800'
1400'
1000'
600'
OUS
B.B.
DEVONIAN
SILURIAN
ORDOVICIAN
PRE-CAMBRIAN
TOWNSHIP 33-34
Mixed Woods
Prairie + Aspen Grove
Man. Lowlands
Pr.+ Aspen Grove
Manitoba Lowlands
English R. Section
Northern Coniferous Section
PLEASANT VALLEY CREEK
HIGHEST STAGE OF LAKE AGASSIZ
LAKE DAUPHIN
LAKE MANITOBA
DOG LAKE
SLEEVE LAKE
PRINCIPAL MERIDIAN
HECLA ISLAND
LAKE WINNIPEG
WANIPIGOW RIVER
1800'
1400'
1000'
600'
ACEOUS
B.B.
DEVONIAN
SILURIAN
ORDOVICIAN
W.S.S.
PRE-CAMBRIAN
TOWNSHIP 24-25
ove
Mixed Woods
RIDING MOUNTAIN
Pr.+ Aspen Grove
Manitoba Lowlands
Prairie and Aspen Grove
Manitoba Lowlands
English River Section
Northern Coniferous
HIGHEST STAGE OF LAKE AGASSIZ
LAKE MANITOBA
PRINCIPAL MERIDIAN
LAKE WINNIPEG
WINNIPEG RIVER
1800'
1400'
1000'
600'
CRETACEOUS
BASAL BEDS
DEVONIAN
SILURIAN
ORDOVICIAN
W.S.S.
PRE-CAMBRIAN
TOWNSHIP 18-19

4 of

5 of


Altitude
1800'
1600'
1400'
1200'
1000'
800'
600'
Assiniboine
Highest stage of Lake Agassiz
Lake Manitoba
Lake Winnipeg
Winnipeg River
Principal Mer.
CRETACEOUS
BASAL BEDS
DEVONIAN
SILURIAN
ORDOVICIAN
W.S.S.
TOWNSHIP 18-19
Prairie and Aspen Grove
Mixed Woods
Prairie and Aspen Grove
R.R. Valley Prairie
Prairie and Aspen Grove
Manitoba Lowlands
2600'
2400'
2200'
2000'
Assiniboine River
Upper stage of Lake Souris
Assiniboine River
Minnedosa River
Brandon
Highest stage of Lake Agassiz
Assiniboine River
Portage La Prairie
Principal Meridian
Winnipeg
CRETACEOUS
BASAL BEDS
DEVONIAN
S.
ORDOVICIAN
W.S.S.
TOWNSHIP 10-11
Southwestern Plains
Mixed Woods
Southwestern Plains
Prairie + Aspen Grove
Red River Valley Prairie
Prairie and Aspen Grove
Manitoba Lowlands
Upper stage of L. Souris
Souris River
Turtle Mountain
Pembina River
Highest stage of Lake Agassiz
Principal Meridian
Red River
CRETACEOUS
TERTIARY
CRETACEOUS
BASAL BEDS
DEVONIAN
ORDOVICIAN
INTERNATIONAL BOUNDARY



6a

SOILS DEPARTMENT, UNIVERSITY OF MANITOBA

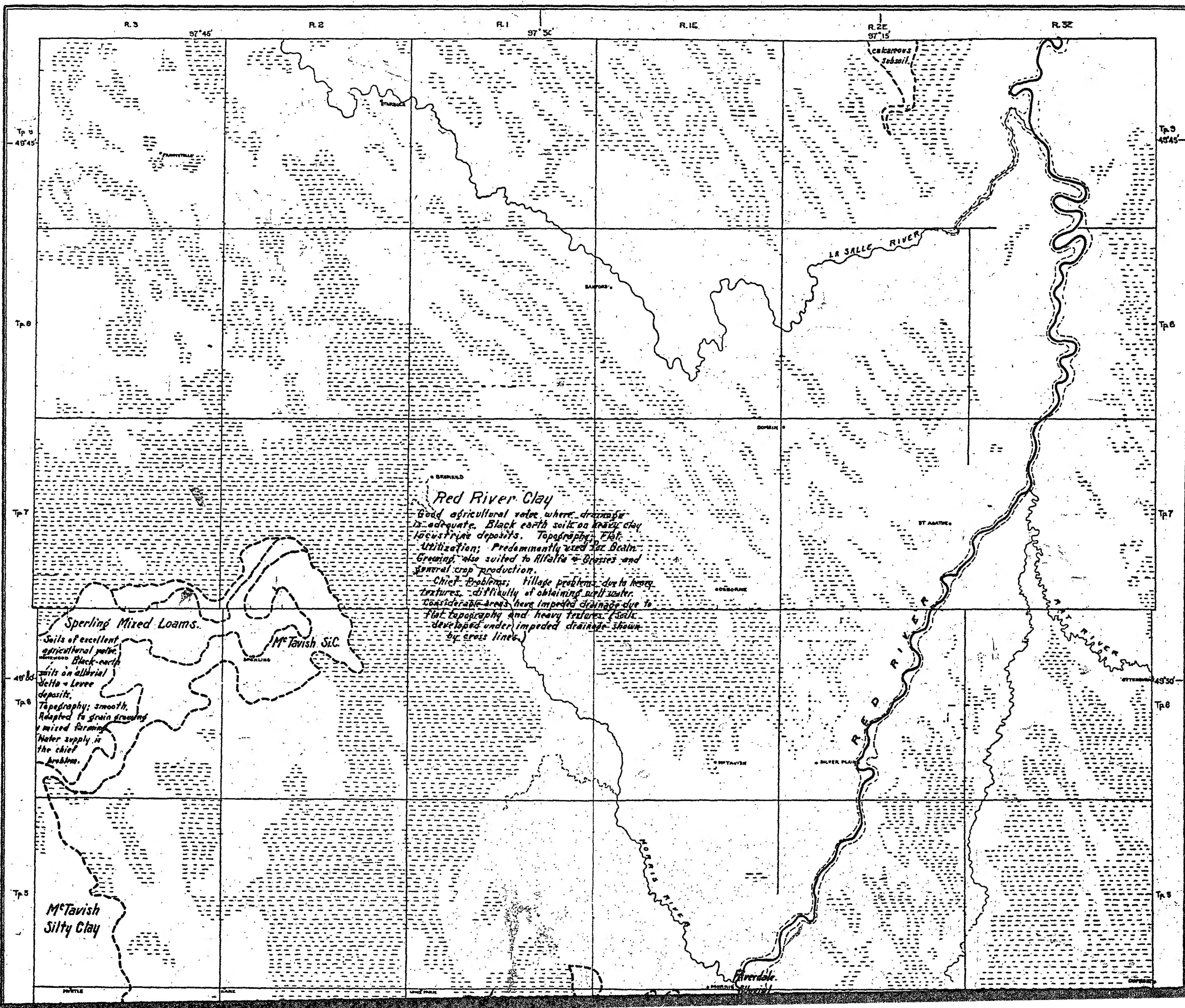
1 of 2

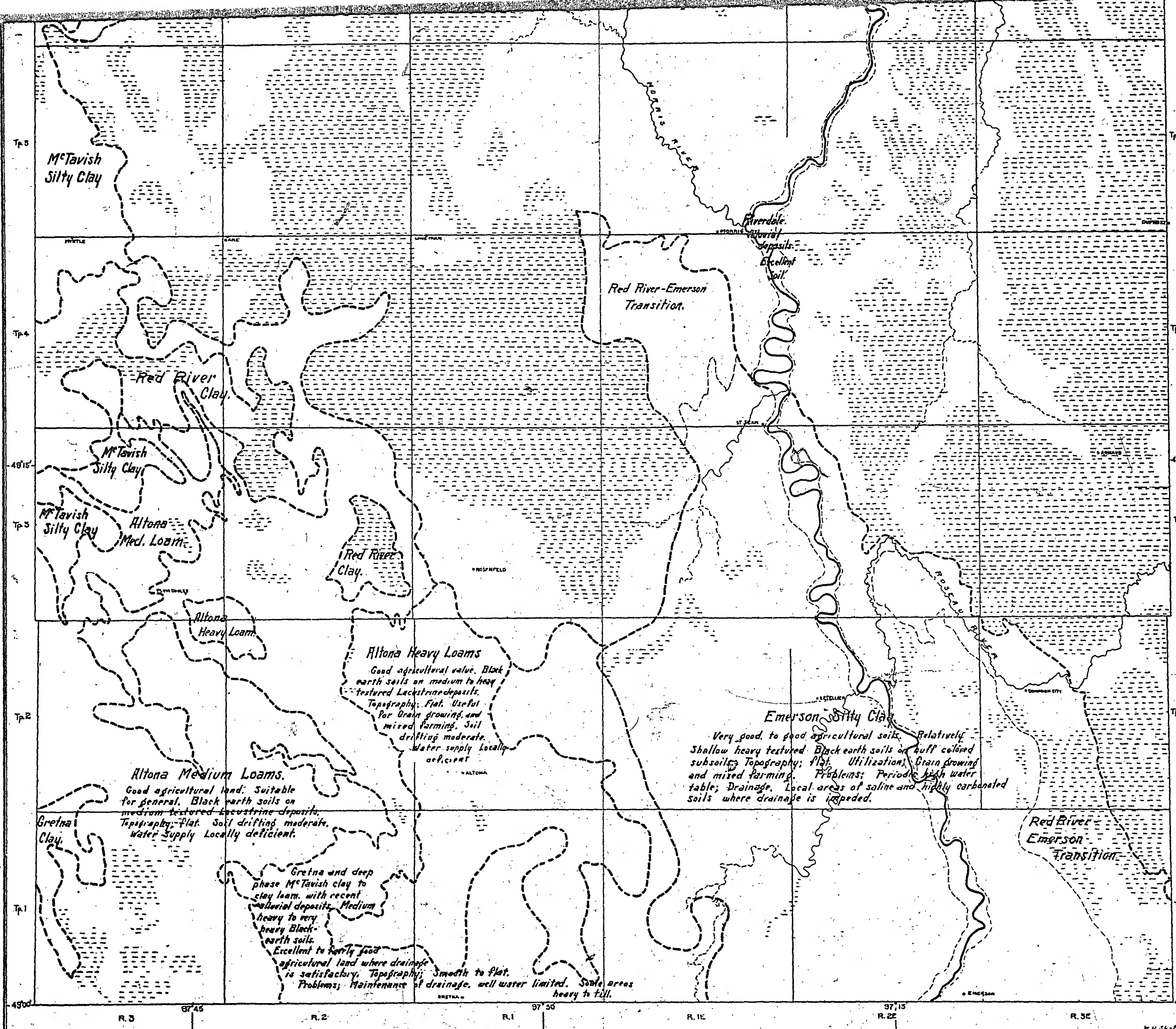
LAND CLASSIFICATION MAP

RED RIVER VALLEY IN MANITOBA

SHEET 3

Scale—One Inch Equals Three Miles





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